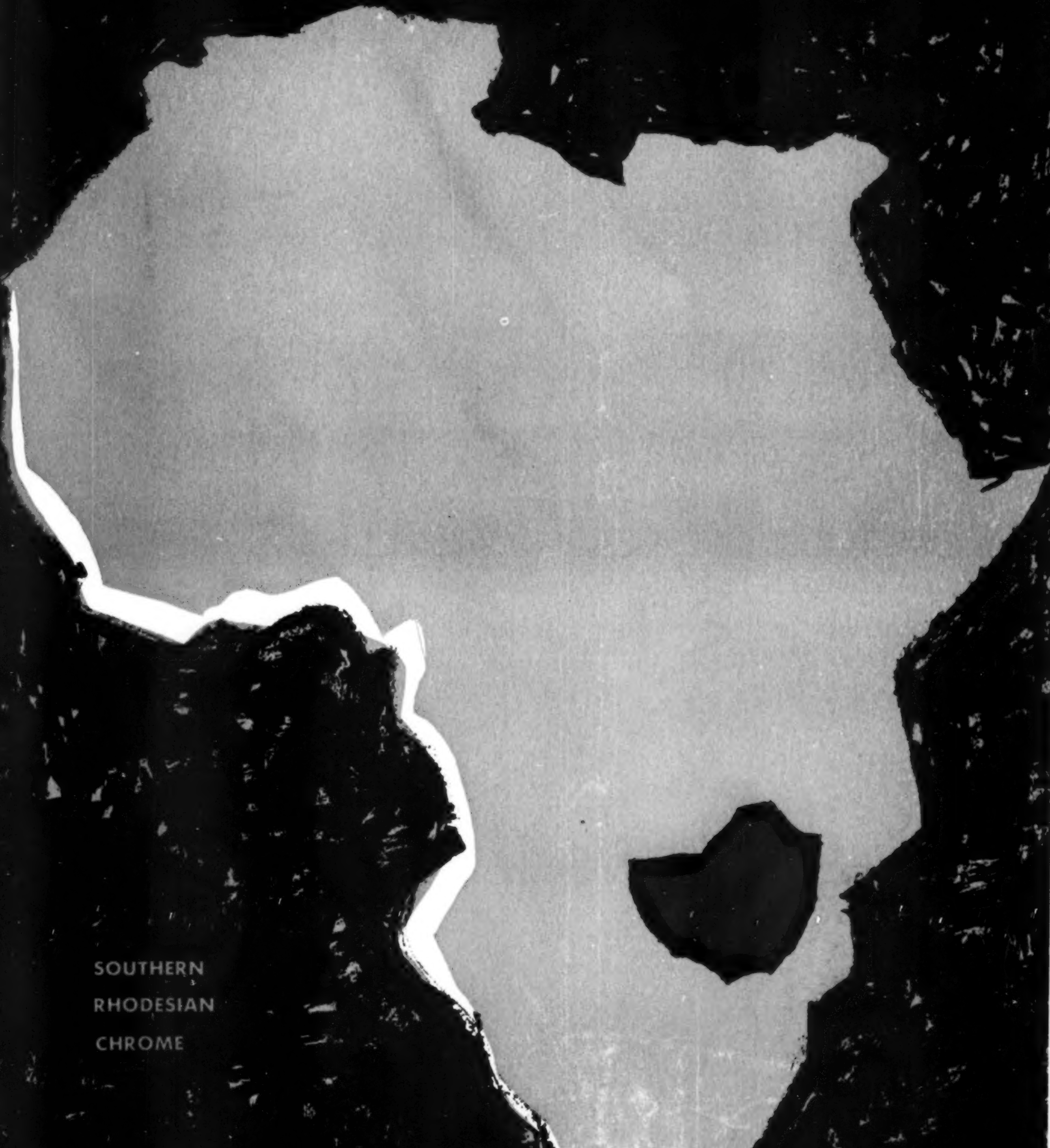
MINING engineering

AUGUST 1954



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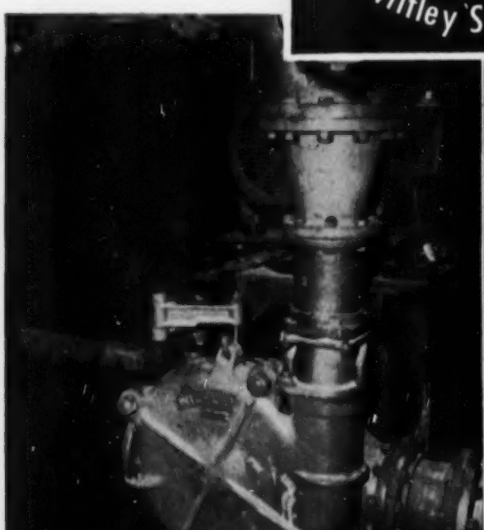

MINING engineering

VOL. 6 NO. 8 AUGUST 1954

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COVER

Cover artist Herb McClure denotes Southern Rhodesia in red on the map of Africa to help us keep our eye on this vital source of chrome. In this issue, starting on page 791, author Parke A. Hodges provides the setting, and fills in the details on mining methods in and along the Great Dike, where Southern Rhodesia chrome production centers.

FEATURES

ARTICLES

TRANSACTIONS

— Personnel Service —

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

MEN AVAILABLE

Mining Engineer, British, graduate School of Mines, Great Britain. Member of British and American Institutes of Mining & Metallurgy. Thirty-four, married, 4 children, veteran. Five years all round experience in underground mining, safety, and ventilation, 3 years civil. Instructor first aid and mine rescue. Resident in Canada. East, West, foreign. M-93.

POSITIONS OPEN

Safety Engineer, with degree, preferably mining; with at least 5 years experience as safety engineer. Location, Arizona. W199.

Junior Engineers, mining graduates, for training program in cement industry, both sales and plant engineering. Locations, New York, N.Y., Pennsylvania, and Midwest. W198.

Head of Dept. of Mining Engineering, 38 to 50, with at least an M.S. in mining engineering, and some good experience in industry. Should also have some teaching experience. Location, Midwest. W188.

Experienced Metal Mining Engineer for mine in Central America. Should have fair speaking knowledge of Spanish. Must be single. Salary, $4200 a year including room, board, and transportation to the property. F174.

Engineers. (a) Mining Engineer, 25 to 35, with some underground mining experience for varied duties at a base metal mine. (b) Mechanical Engineer or equivalent, 25 to 35, with some experience in general mine construction and maintenance for a position in the mechanical dept. of a base metal mine. Knowledge of Spanish desirable. Salaries, $4200 a year. Location, Mexico. F95.

General Manager and Administrator, graduate mining engineer, who has considerable placer mining experience and a complete understanding of dredging operations. Salary open. Housing available for man and wife. Location, French Guiana. F170.

Chief Mine Engineer-Geologist, graduate, 30 to 40, with some mining and geological experience for mine in Nicaragua. Salary, $7200 a year. Free house for applicant and family, medical expenses, etc. F116.

Metallurgical Engineer, to take charge of the metallurgical problems of a mining operation. He should have a thorough knowledge of flotation, cyanidation, lixiviation, and if possible, some knowledge of running a sulphuric acid plant. Accommodations for man and wife only. Salary open. Chile. F172.

Mine Superintendent, must have several years underground experience and be able to speak Spanish fluently. Central Mexico. F202.

WANTED—Responsible mining engineer to investigate properties and share in costs of exploration development and operation in return for percentage of profits. Submit full details of experience.

Box G-10 AIME

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WANTED: Assistant Superintendent in a combined Mechanical and Electrical Department of a long established underground mining operation in East Tennessee.

Successful applicant should have had several years' experience in maintenance, and preferably, but not necessarily, be a technical graduate in electrical engineering.

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METALLURGICAL SUPERINTENDENT

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Metallurgical Superintendent

to Rhokana Corporation Limited, Kitwe, Northern Rhodesia.

The position necessitates an extensive knowledge of copper metallurgy, and administrative experience in a senior executive capacity is essential. Preference will be given to applicants between the ages of 40 and 50 years.

Responsibilities include the supervision and direction, through Plant Superintendents, of complex metallurgical operations involving the concentration, reverberatory smelting and electrolytic refining of copper on a large scale, as well as ancillary operations such as the production of sulphuric acid from converter gases.

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Initially, the engagement will be for a period of three years, but service may be extended indefinitely by mutual agreement.

The salary to be offered will be commensurate with the successful candidate's qualifications and experience. In addition, a Cost of Living Allowance is paid, and a Cash Bonus, based on the difference between the production cost and selling price of copper, at present amounting to over 60% of basic salary, accrues. Membership of the Corporation's Pension Fund is obligatory.

The Corporation will bear the cost of first-class transportation for the successful candidate and his family, including children up to the age of eighteen years, to Kitwe, Northern Rhodesia. In addition, an allowance will be made to cover the reasonable cost of transporting personal effects of the appointee, other than heavy furniture. On expiration of the contract, repatriation expenses will again be borne by the Corporation.

A house, complete with heavy furniture and certain furnishings, will be available immediately, free of charge.

Excellent medical facilities are provided, and recreational facilities are outstanding. The climate is temperate and healthy.

Applications, stating age, marital status, educational and professional qualifications, details of past experience and positions held should be addressed to:—

The General Manager,
Rhokana Corporation Ltd.,
P.O. Box 137,
Kitwe,
Northern Rhodesia.

Candidates are expected to be physically active and a medical certificate of health must accompany applications.

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Meet The Authors

B. Langston (p. 883) has been with Battelle Memorial Institute since 1948. He joined Battelle after graduation from University of Alabama with a B.S. in chemistry and metallurgy. Mr. Langston was co-winner of the Journal of Metals Award in 1953 for his paper *The Reduction Oxidation Process for the Treatment of Taconite.* Another paper, *Recent Developments in the Thermal Drying of Fine Coal,* appeared in the *Revue de l'Industrie Minérale,* April 1951. He is extremely interested in the use of the movie camera for the study of technical problems. Another pastime is golf.

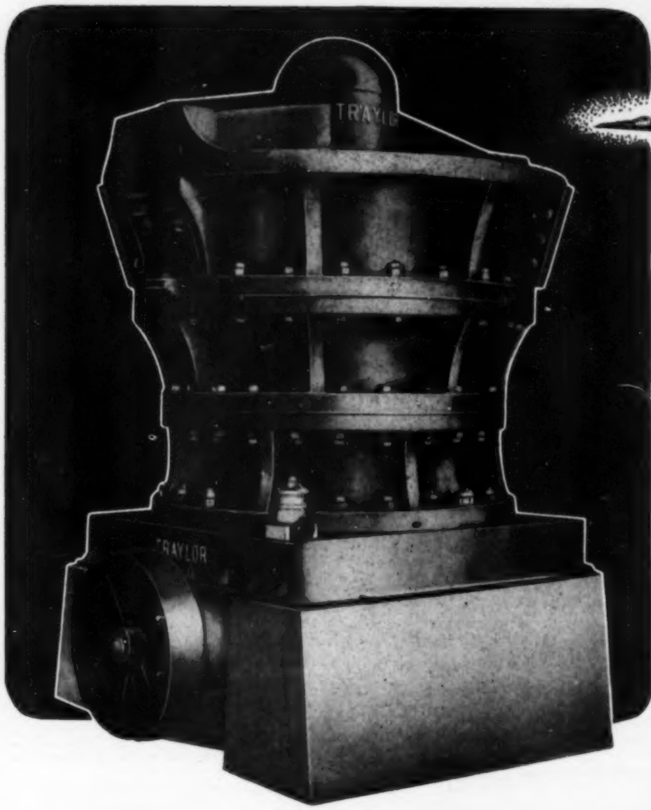
R. H. Nesbitt (p. 805), Dept. of the Army, Office of the Chief of Engineers, was almost a natural to become associated with the NX borehole camera. He is currently assistant chief geologist of the Office of the Chief of Engineers, and he's vitally interested in photography. He earned his A.B. at Muskingum College and an M.A. at Ohio State University. His earlier paper called *The Work of the Geologist in Civil Engineering* was published by the *Engineering Experiment Station News* at Ohio State. He is a member of Sigma Gamma Epsilon, Sigma Xi, Phi Beta Phi, and more recently, a fellow of the Geological Society of America and of the AAAS.

H. Wilton-Clark (p. 825) was born in Birmingham, England, but now lives in Coleman, Alberta, Canada. He is a graduate of the University of Alberta, holding a B.S. in mining engineering. At the university he was president of the Engineering Students Society, and won the Mining Engineering Award. Mr. Wilton-Clark is with Coleman Collieries Ltd., Coleman, Alberta. Memberships include the Professional Engineers Assn., Alberta; Canadian Institute of Mining and Metallurgy, and Institution of Mining Engineers, London. When Mr. Wilton-Clark gets the chance, he grabs his trout rod and heads for the nearest stream for a try at the big ones.

F. M. Stephens, Jr., (p. 833) is chief of the Extractive Metallurgy Div., of Battelle Memorial Institute. He has been with Battelle since 1942. A graduate of the Colorado School of Mines, he is a member of Sigma Gamma Epsilon, and Tau Beta Pi. While at school he was a member of the Press Club, Alpha Tau Omega, and business manager of the school paper. Mr. Stephens was a co-winner of the 1953 Journal of Metals Award for *The Reduction Oxidation Process for the Treatment of Taconite.* Another recent paper by Mr. Stephens is *Fluidized-Bed Sulphate Roasting of Nonferrous Metals.* Hobbies are automobiles, woodworking, and golf.

119,000,000 tons

AND STILL GOING STRONG



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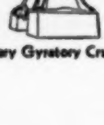
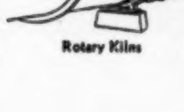

Primary Gyratory Crushers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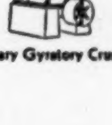
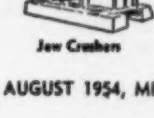

Secondary Gyratory Crushers


Ball Mills

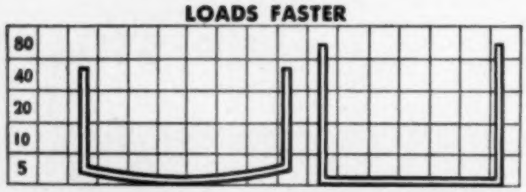

Jaw Crushers


Apron Feeders

Compare these dirt-moving features before you buy

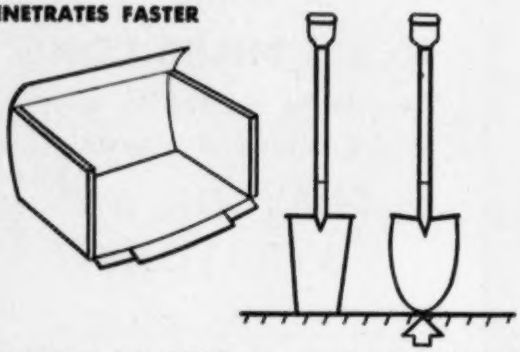
Check over these Allis-Chalmers TS-200 Motor Scraper features point by point. See for yourself how performance makes dollars when design makes sense.

LOADS FASTER



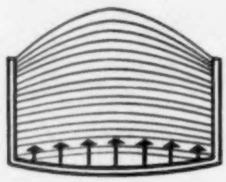
Tests have proved that loading resistance is largely determined by the height to which the load is built. That's why the lower, wider bowl of an Allis-Chalmers Motor Scraper requires less time and power to get the same yardage.

PENETRATES FASTER



The penetrating ability of a round-end spade helps illustrate how the curved and offset cutting edge on Allis-Chalmers Motor Scrapers concentrates all the horsepower on the center section during initial penetration.

HEAPS AUTOMATICALLY



The combination of slightly deeper center cut and correctly angled cutting edge shapes the load as the scraper fills. The greater volume of dirt flowing into the center of the bowl "boils" forward, to the rear and to the sides, producing an automatically heaped load without excessive spillage.

SPREADS EVENLY

Forward movement of ejector is timed with lifting action of apron, which provides a continuous flow of material to insure a smooth, even spread. High apron lift prevents any possibility of material's jamming.

AT HOMESTAKE MINING COMPANY

Eight Dorr Thickeners in slimes circuit average 21 cents per unit per year for repair parts cost.

Closeup of drive mechanism of one of the eight Dorr Thickeners in the Homestake slimes circuit. This particular 24′ diameter unit has been operating since 1914.

HOMESTAKE MINING CO.

HERE'S THE REPAIR PARTS COST RECORD

Number of Units	Size and Type of Thickeners	Years of Operation	Repair Parts Costs Total	Per Year
1	44 ft. Special	38	None to date	
1	24 ft. Special	36	$45.70	$1.27
2	23 ft. Special	35	None to date	
1	54 ft. Type N	23	None to date	
1	54 ft. Type N	21	None to date	
1	54 ft. Type R	17	None to date	
1	60 ft. Type R	16	None to date	

In the period 1911 to 1933, Homestake ordered eight Dorr unit-compartment Thickeners of varying types and sizes for slimes thickening. As shown in the table above, the maintenance record of these units is adequate testimony that they were built to last.

Light duty in the slimes circuit — sure. We'll also have to admit to remarkably careful and efficient operation on the part of Homestake over the years. But bear in mind that these are light machines — built for light duty — and are still going strong after 16 to 38 years of continuous operation.

We wouldn't suggest that you can expect "no repair" performance on every Dorr Thickener regardless of type of duty. Point is, though, when you buy Dorr you buy minimum repairs. More important still, you buy minimum shut-down time and maximum production. The Dorr Company, Stamford, Conn., or *in Canada*, The Dorr Company, 26 St. Clair Avenue East, Toronto 5.

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Increase your footage

Use CLEVELAND Air Legs and Drills...the easiest way

THE FEED YOU NEED — FROM ZERO FEED TO FULL LINE

Eleven detent positions enable drill operator to set and maintain pressures in a range from zero to full-line feeding pressure — with an increase of 9 psi at each setting. That's why a CLEVELAND Air Leg and H10AL Drill combination gives top performance in any kind of rock.

Shown here is a **CLEVELAND AL-92** Telescopic Air Leg with H10AL Drill. Because of space limitations, full length isn't shown.

CLEVELAND AL-92 Telescopic Air Leg with H10AL Drill and exclusive 11-position feed control

SPECIFICATIONS

Standard, automatic controlled wet-type backhead.

Chuck Sizes	⅞″ x 4¼″ — or other popular steel shank sizes	
Weight, Drill	60 lbs.	
Air Hose	¾″	
Water Hose	½″	
Full Feed Travel	4′	6′
Collapsed Feed	2′ ea. piston	3′ ea. piston
Closed Length	48″	60″
Extended Length	96″	132″
Air Leg Weight	37 lbs.	42 lbs.

CLEVELAND AL-90 Single Extension Air Leg for use with H10AL Drill and exclusive 11-position feed control

SPECIFICATIONS

Weight, Drill	60 lbs.
Air Hose	¾″
Water Hose	½″
Feed Travel	36″ — 48″ — 60″
Closed Length	56¾″ — 69″ — 81¼″
Extended Length	92¾″—117″—141¼″
Air Leg Weight	30 lbs.—34 lbs.—37 lbs.

CLEVELAND AL-91 Single-Extension Air Leg for use with any 35-lb., 45-lb., or 55-lb. class rock drill. Feed control built into air leg.

SPECIFICATIONS

Standard wet, or automatic controlled, wet-type backhead available.

Air Hose	¾″
Water Hose	½″
Feed Travel	36″ — 48″ — 60″
Closed Length	58″ — 71″ — 83″
Extended Length	94″ — 119″ — 143″
Air Leg Weight	35 lbs.—38 lbs.—41 lbs.

per man-shift!

to drill rock

Choose
the drilling combination
that's best for you
from the industry's only
complete line of telescopic
or single-extension air legs.

MINERS like to use a CLEVELAND Air Leg and H10AL Drill combination. It gives them real flexibility — they can use it as a drifter . . . as a stoper . . . or as a hand-held drill . . . set-ups are quick and easy.

It's an easy-handling combination, also. The air leg supports the drill and absorbs fatiguing recoil. You get flexible feeding pressure, too — from zero to full line. That's why miners drill more footage with CLEVELAND, yet are less tired at the end of their shift.

Exclusive CLEVELAND built-in feed control in the H10AL Drill eliminates a third hose and cumbersome "Y" connections. There's no feed-control bleed valve — the operator doesn't have to bleed off air continuously, to maintain suitable feeding pressure. He can change or advance the position of the leg easily and quickly.

The air leg holds the drill in line with the hole — thus reducing front-end drill wear and practically eliminating rotation strains.

These are ways a CLEVELAND Air Leg and H10AL Drill combination helps you get more drilling for less cost. Take advantage of them.

Write today for Bulletin RD-30 for complete information.

CLEVELAND AL-93 Telescopic Air Leg for use with any 35-lb., 45-lb., or 55-lb. class rock drill. Feed control built into air leg.

SPECIFICATIONS

Full Feed Travel	4'	6'
Collapsed Feed	2' ea. piston	3' ea. piston
Closed Length	50"	62"
Extended Length	98"	134"
Air Leg Weight	42 lbs.	47 lbs.

CLEVELAND ROCK DRILL DIVISION

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A Subsidiary of Westinghouse Air Brake Co.

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Realistic Depreciation Policy, by George Terborgh, research director, *Machinery & Allied Product Institute,* $6.00, 222 pp., 35 charts, 15 tables, 1954.—This book presents detailed answers to such questions as: What is the pattern of capital erosion? For equipment? For buildings? Why has business, under existing U. S. tax depreciation policy, found it difficult to adopt depreciation methods conforming to the pattern of capital erosion? What proposals for the reform of tax depreciation policy have been forwarded and what are their advantages and disadvantages?

Select Methods of Metallurgical Analysis, by William Archibald Naish, John Edward Clennell, and Victor S. Kingswood, *Chapman & Hall Ltd.,* London, approx $10.50, 660 pp., 2nd revised ed., 1953.—The six parts of this book cover the essential chemistry of the methods presented; analysis of the elements; analysis of commercial metals, iron and steel, and ferrous and nonferrous alloys; analysis of ores and slags; analysis of refractory materials, coal, and coke; and modern physicochemical methods. Selection has been made of the most rapid, accurate, and practical methods for the use of metallurgical chemists and professional analysts.

Ferrous Process Metallurgy, by John L. Bray, *John Wiley & Sons Inc.,* $6.50, 414 pp., 1954.—Designed as a college textbook, this book is based on careful study of the two editions of *Ferrous Production Metallurgy* by the same author. In writing this the late Mr. Bray kept in mind that a college text should: contain condensed descriptions of equipment, accompanied by simple line drawings, to avoid confusion created by the multiplicity of detail involved in working drawings; avoid use of photographs as unduly expensive and ineffective; and keep statistical material to a minimum. The book is aimed at a junior or senior year class.

Sudbury Basin, The Story of Nickel, by D. M. LeBourdais, *Ryerson Press,* Toronto, $3.00 Can., 210 pp., 1953.—The author of *Canada's Country* and *Nation of the North* has written of the history and development of a Canadian frontier community into a city of 50,000 people supported entirely by metals. Mr. LeBourdais contends that metals and other products of the earth below its first few inches will ultimately prove the basis for Canada's culture, rather than agriculture as in the past. The cost of writing this book was underwritten by Falconbridge Nickel Mines Ltd. and it was H. J. Fraser, vice president and general manager of Falconbridge, who first interested the author in Sudbury. Excellent photographs and maps.

(Continued on page 762)

Please Order the Publications Listed Below from the Publishers

California Journal of Mines and Geology, Vol. 50, No. 2, April 1954, *Dept. of Natural Resources,* Div. of Mines, Ferry Bldg., San Francisco 11, $1.00, 430 pp., 2 maps in pocket.—This is a quarterly issued in January, April, July, and October. This issue contains "Nineteenth Century Mines and Mineral Spring Resorts of Lake County, Calif." and "Mines and Mineral Resources of Santa Clara County, Calif." The Div. of Mines also publishes a monthly news release, *Mineral Information Service,* distributed free of charge upon request.

Barite Deposits Near Barstow, San Bernardino County, Calif., by Cordell Durrell, *California Dept. of Natural Resources,* Div. of Mines, Ferry Bldg., San Francisco 11, Special Report 39, 50¢, 8 pp., 4 pl., 1 fig., 1954.—The material in this report was compiled from field studies made during the latter part of World War II.

Oregon's Gold Placers, Miscellaneous Paper No. 5, compiled by the Staff, *Oregon Dept. of Geology & Mineral Industries,* 1069 State Office Bldg., Portland 1, Ore., 25¢, 14 pp., 1954.—This illustrated booklet was compiled to answer requests received on location of gold placers and placer mining in Oregon. The material is mainly from *The Ore.-Bin,* but a portion of the USGS circular No. 8, "Beach Placers of the Oregon Coast," by J. T. Pardee, was included to cover the subject of gold placers on present beaches and ancient elevated beach terraces.

Report of Investigations No. 20, Cretaceous of Llano Estacado of Texas, by John P. Brand, 70¢, 59 pp., 14 fig., 4 heliotype pl., map, 1953. **Report of Investigations No. 23,** Phosphorite in Eastern Llano Uplift of Central Texas, by Virgil E. Barnes, 15¢, 9 pp., 2 fig., 1954. *Bureau of Economic Geology, University of Texas,* University Station, Box 8022, Austin 12, Texas.

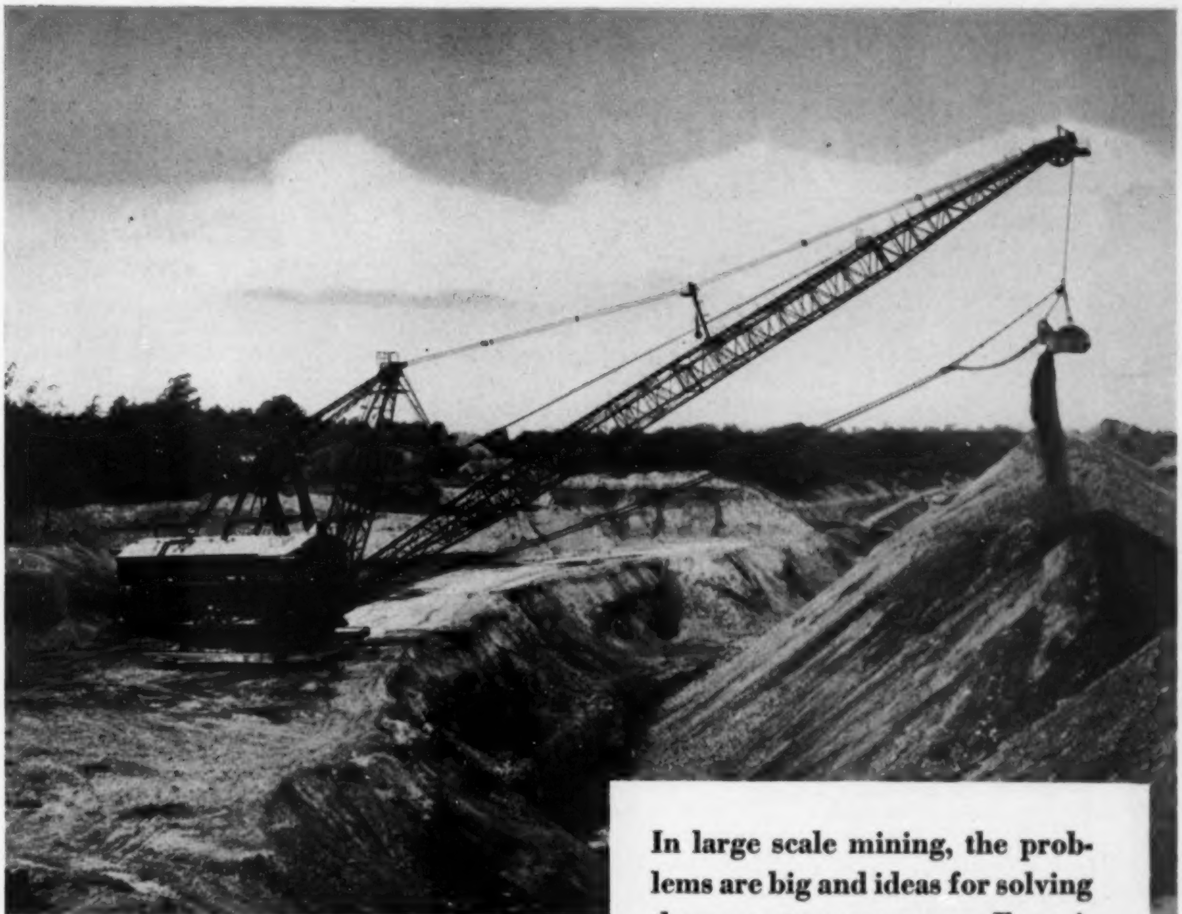
Analysis Directory of Canadian Coals, by E. Swartzman, *Dept. of Mines & Technical Surveys,* Mines Branch, Fuels Div., Ottawa, Canada, $2.50 Can., No. 836, 204 pp., 2nd ed., 1953.—This revision of the 1948 edition includes all analyses available in the records of the Fuel Div. to December 1952 and certain special samples obtained in 1953. Appendix I contains analyses of U. S. and British anthracites and Appendix II gives the range of ash content.

Interpreting Geologic Maps for Engineering Purposes, Chief of Distribution, *U. S. Geological Survey,* Washington 25, D. C., or Distribution Center, USGS, Federal Center, Denver, Colo., $1.75.—A set of six maps showing some of the practical uses of geologic maps. The set contains a standard topographic map and a general purpose geologic map of the Hollidaysburg quadrangle in south central Pennsylvania; three interpretative maps of the same quadrangle and a map showing the contribution geology can make to the solution of hypothetical problems.

Air Pollution Abatement Manual, *Mfg. Chemists' Assn. Inc.,* 1625 Eye St., Northwest, Washington 6, D. C., $6.00, individual chapters 15¢ to 75¢.—This manual after nearly 5 years of work by recognized chemical industry experts is now complete. Produced under the editorship of C. A. Gosline, engineering dept., E. I. du Pont de Nemours & Co., it includes information on types of air pollution, legislative requirements, technical methods of handling problems, and suggestions for enlisting the cooperation of employees, industrial and public officials, and the public itself.

Reinforced Concrete Reservoirs and Tanks, by W. S. Gray, *Concrete Publications Ltd.,* 14, Dartmouth St., London, S.W. 1, England, $2.80 post free, 170 pp., 132 illustrations, 15 tables.—The 18 sections into which this book is divided include gasholder and tar tanks, shallow circular tanks of large diameter, open reservoirs, tanks with conical or pyramidal floors, design and construction methods, repairs, and Dr. Reissner's method of calculating direct forces and bending moments on the walls of cylindrical tanks.

Interpretations of the Structural Geology of the Sherridon-Flin Flon Region, Manitoba, by J. Kalliokoski, Geological Survey of Canada, Bulletin 25, *Dept. of Mines & Technical Surveys,* Ottawa, Canada, 50¢ Can., 18 pp., map in pocket, 1953.



In large scale mining, the problems are big and ideas for solving them must measure up. Experienced strip mine operators know that Bucyrus-Erie stripping shovels and draglines offer the right answer — really big output, along with dependability and economical operation. In addition they provide long working ranges, time-saving maneuverability, and the basic simplicity of design that means low maintenance costs.

If your mining operation requires the economical handling of big yardages, investigate Bucyrus-Erie stripping shovels and draglines. 17L54

No place for little ideas...

BUCYRUS ERIE

South Milwaukee, Wisconsin

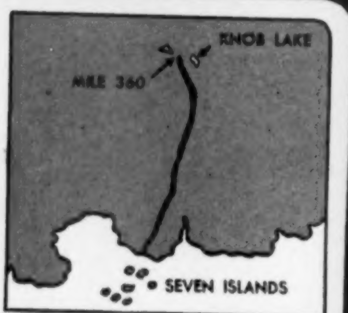
Proving its mettle

GM DIESEL
CASE HISTORY No. 53-233

USER: Iron Ore Company of Canada

INSTALLATION: 12 GM Diesel-powered 34-ton Euclid IFFD trucks and 5 Allis-Chalmers HD-20 tractors used to strip and haul at Knob Lake. Part of a fleet of more than 200 GM Diesel engines powering all types of equipment for I.O.C.

PERFORMANCE: "They're doing a wonderful job," said Master Mechanic "Jock" Marshall. "Equipment takes a real licking up here, and GM Diesels stand up under it."



More than 200 GM Diesel Engines on vast Ungava Project

Up at "the Knob," 360 miles above Seven Islands terminal, the Iron Ore Company of Canada relies on General Motors Diesel-powered equipment—just as it has in construction of railroad, dams and facilities all along the line.

The big double-engine "Euc" and HD-20 shown above are benching access road to the rich Ruth Lake #3 deposit, first in the area to be opened for mining. They are part of a GM Diesel-powered fleet that proved its mettle by "walking" to the end of the line under its own power—a 250-mile trek over frozen tundra in blizzards and temperatures that reached 40° below zero.

These quicker-starting, faster-accelerating 2-cycle Diesels have been delivering trouble-free performance on double-shift, 20-hour-a-day schedules ever since they arrived—a tribute to both their rugged stamina and I.O.C.'s excellent preventative maintenance program.

Whatever your need for power—in trucks, tractors, air compressors, cranes, shovels—why not learn firsthand how much more profitably and dependably this versatile GM 2-cycle Diesel can deliver it? There is a GM Diesel distributor near you who will gladly give you all the facts—and you can count on him for prompt, efficient parts supply and service wherever you are.

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GM GENERAL MOTORS DIESEL POWER

keeping air pressure UP THOUSANDS of feet DOWN

At the Silver Summit Mine in Osburn, Idaho, in a vaulted room more than 1,000 feet below the surface, an Ingersoll-Rand PRE compressor (shown below) converts electric power into air power used to help tear silver, copper and lead ores from the earth.

This spic and span installation, shown below, is reached through a tunnel 6,000 feet long. The 400-hp compressor provides air for mine workings as far as 3,400 feet below it.

Placing the compressor underground has two advantages: First, it eliminates costly piping that otherwise would be necessary to transmit compressed air more than a mile from a surface plant to the working shaft. Second, it avoids air pressure losses that would be caused by leakage and the friction of air passing through a mile-long pipe.

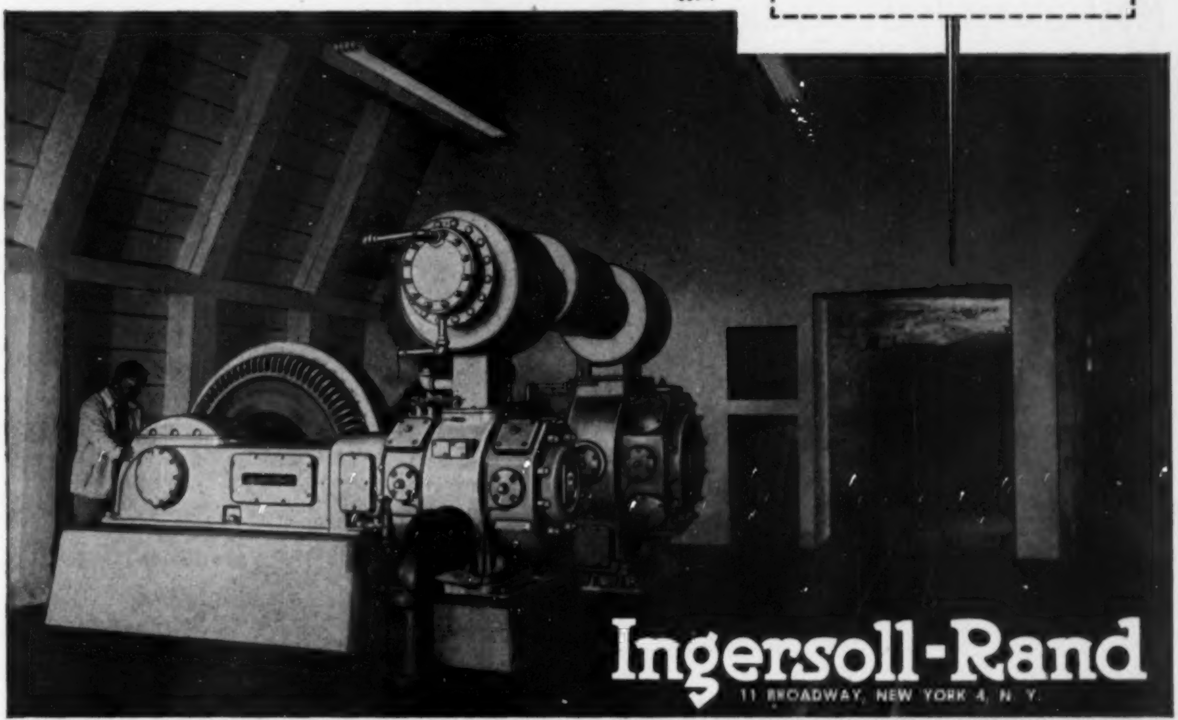
This is not the first underground PRE installation for the Hecla Mining Company whose management controls the operation of Silver Summit Mining Co. It had previously relocated one unit at its Star Mine from the surface plant to an underground station where it also installed a new PRE. This step eliminated the surface plant and the pressure losses formerly caused by 11,000 feet of air piping. Several other I-R compressors have been serving Hecla's older properties for more than 30 years.

Long recognized as a leader in using modern mining equipment to increase production, Hecla mines employ many Jackhamers, drifters, Jackbits, hoists, pumps, and other I-R products.

861-1

FEATURES OF THE "PRE" COMPRESSOR

- Crankcase need not be opened for bearing adjustments . . . stays clean.
- Main bearings have micrometer adjustment from outside of crankcase.
- Full-floating crankpin and crosshead-pin bearings result in long bearing life.
- Unique, built-in, force-feed running gear lubrication eliminates piping both inside and outside compressor.
- I-R stainless-steel Channel Valves are efficient and durable.
- Automatic 5-step full Clearance Control regulates compressor output.
- Built for continuous full-load operation . . . for air or any gas . . . for any pressure . . . sizes from 300 to 3000 hp.



COMPRESSORS • AIR TOOLS • ROCK DRILLS • TURBO BLOWERS • CONDENSERS • CENTRIFUGAL PUMPS • DIESEL AND GAS ENGINES

Books for Engineers

(Continued from page 758)

1954 International Petroleum Register, *Palmer Publications,* $15.00, 31st edition, 650 pp., 1954.—A list of more than 25,000 companies that produce, refine, drill, transport, process, and compound petroleum and its products. Officers, capitalization value, properties, production record, and areas of operation are itemized in many cases. A new feature is a list of more than 18,000 wholesale distributors of petroleum products arranged alphabetically by states. State rules and regulations for transporting these products are also given.

The Measurement of Particle Size in Very Fine Powders, by H. E. Rose, *Chemical Publishing Co. Inc.,* $2.75, 127 pp., 1954.—Recent developments and research in progress in the field are reviewed in four lectures which provide data for the choice of techniques for measuring fine powders in the size range 0.001 to 0.06 mm. Some of the methods discussed are elutriation, sedimentation, photo-extinction, and nitrogen adsorption.

Structural Geology, by Marland P. Billings, *Prentice-Hall Inc.,* $9.25, 514 pp., 2nd edition, 1954.—Previously described as a "truly comprehensive work valuable as a textbook for geology students" and "an essential reference work for trained geologists," this new edition follows the same general policy as before with emphasis placed on principles of structural geology. Three new exercises have been added to the structural problems at the end of the book and some of the other exercises have been modified.

The Techniques of Supervision, by Alfred R. Lateiner in collaboration with I. E. Levine, *National Foremen's Institute Inc.,* cloth bound $4.00, distributive edition 2 for $4.00.—Designed for "white and blue-collar" supervision, this work contains "tested ideas, techniques, and methods of supervision found successful by management people in industry and business." Various sections are entitled "Five Ways to Improve Morale," "Discipline," "Accident Control," "Check Your Supervisory Know-How," "A Code for Foremen."

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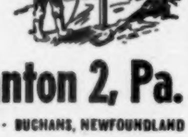

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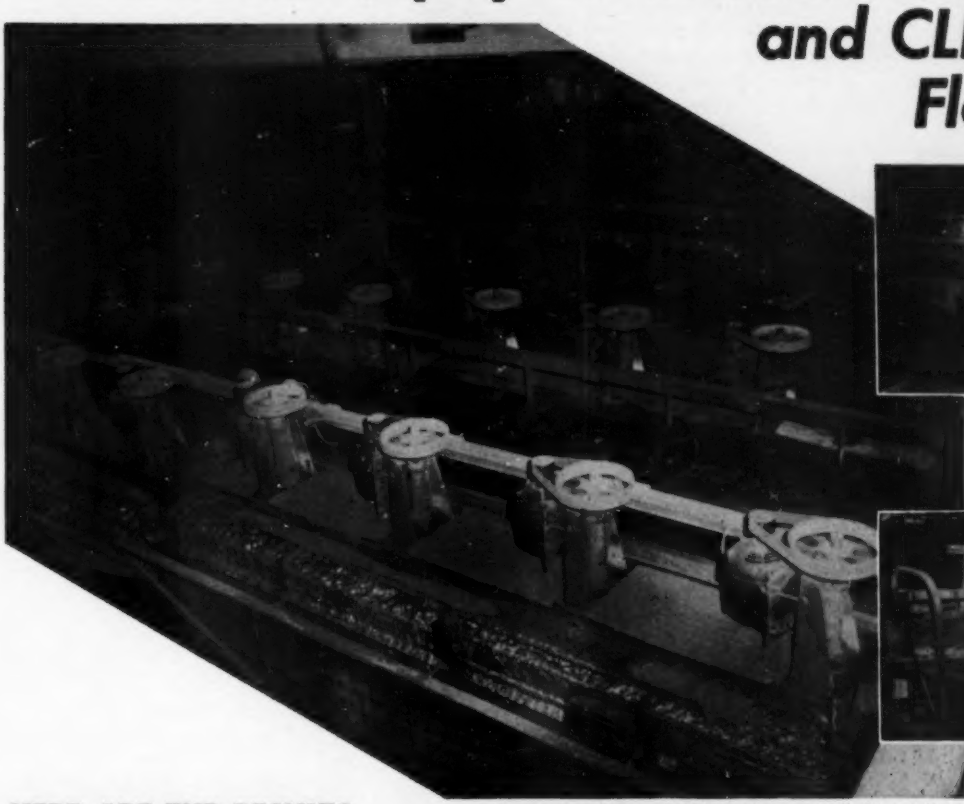
Please Order the Books Listed Below from the Publishers

Field Conference Guidebook No. 7, Salem Limestone and Associated Formations in South-Central Indiana, by T. G. Perry, N. M. Smith, and W. J. Wayne, 50¢, 73 pp., 5 pl. **Miscellaneous Map No. 4,** Map of Indiana showing average magnetic intensity. Scale 1:500,000 50¢. **Miscellaneous Map No. 5,** Map of Indiana showing gravitational intensity. Scale 1:500,000 50¢. **Coal Investigation Map No. C 16,** Geology and Coal Deposits of the Hymera Quadrangle, Sullivan County, Ind. (published by USGS in cooperation with Indiana Geological Survey) $2.00. **U. S. Geological Survey Circular No. 266, Coal Resources of Indiana,** by Frank D. Spencer (prepared in cooperation with the Indiana Geological Survey) free, 42 pp., 16 fig., 11 tables. Publications Section, *Geological Survey, Indiana Dept. of Conservation,* Bloomington, Ind.

Manganese in the Iron and Steel Industry, *Organisation for European Economic Cooperation,* Paris. Available in U. S. from O.E.E.C. Mission, Publications Office, 2002 P Street, N.W., Washington 6, D. C., 75¢, 45 pp., 1953.—The problem of manganese consumption and recovery in Member Countries. Some statistical data on manganese supplies and a brief description of some methods used in the U. S. and Europe for recovering manganese are also included.

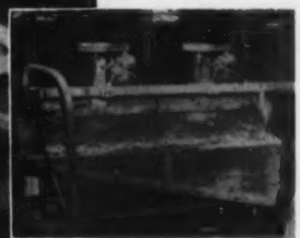
The Design and Use of Belt Conveyors in Mines, by A. Grierson, *The Mining Journal,* 15 Wilson St., Moorgate, London, E.C.2., England, 2s. 6d. (approx. 35¢ including postage), 40 pp.—The author is a lecturer in mining at the Royal School of Mines. His short monograph, recently serialized in *The Mining Journal,* is brief, practical, and readable.

FAGERGRENS *pay off in both* ROUGHER and CLEANER Flotation



Fagergrens used for rougher flotation by Pend Oreille Mines & Metals Co., Metalline Falls, Wash. Zinc circuit in foreground, lead circuit in center; duplicate circuits being installed in background.

Fagergren cells in lead cleaner flotation circuit.



Fagergren cells in zinc cleaner flotation circuit.

HERE ARE THE RESULTS OBTAINED BY A MAJOR LEAD-ZINC PRODUCER

48 Fagergren Flotation Machines are used by Pend Oreille Mines & Metals Co. in flotation circuits having a capacity of 1600 tons per day. The ore is hard and abrasive with lead (as galena) occurring in coarse crystals and zinc (as sphalerite) finely disseminated in the gangue. Specific gravity of ore is 2.7 to 2.8.

Fagergren's highly efficient performance in this application produces superior metallurgical results, as follows:

1. Lead concentrate grade averaging well over 70% lead.
2. Zinc concentrate grade running close to 60% zinc.
3. Recoveries of approximately 95% lead and zinc in respective concentrates.
4. Exceptionally low lead and zinc tailing assays.

High Metallurgical Efficiency, as demonstrated above, is not unusual with Fagergrens. It is based on the faster rate of flotation and greater flotation recovery made possible by Fagergren's exclusive Rotor-Stator design. This superior agitating mechanism is unmatched for effective pulp circulation and aeration with resulting greater capacity per cubic foot of cell volume and higher mineral recovery.

Specify Fagergrens for your next installation or as replacements for older, less efficient machines. Send today for free copy of Fagergren descriptive bulletin and for recommendations concerning your flotation problem.

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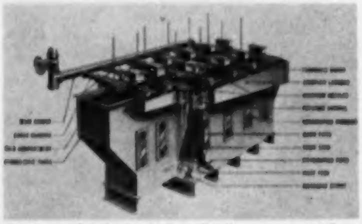
Pocket pH Meter

A pocket-size analytical pH meter and companion probe unit from *Analytical Measurements Inc.* aims to permit instant, on-the-spot pH determinations anywhere and eliminate need for grab samples and trips to the lab. **Circle No. 1**

Hydraulic Sizer

The Dorr Co. announced the availability of the Dorrco Jet Sizer, a hindered settling hydraulic classifier for sizing in the —8 mesh range. New



design features result in more effective use of hydraulic water to produce clean fractions sized within narrow limits. Number of pockets ranges from 1½ to 21½, with flexible arrangement singly, in series, or in transverse banks of two, three, or four abreast. Novel use of small nozzles eliminates expensive constriction plate. **Circle No. 2**

I-R Drillmaster

Full story on a new self-contained and self-propelled twin-drill rig is available from *Ingersoll-Rand.* De-

signed to cut cost and speed operation on heavy duty wagon drill jobs, the Drillmaster has two hydraulic booms, two 10-ft drill towers, two X-71-WD drills, a rugged crawler assembly, and a 600-cfm Gyro-Flo rotary compressor in one mobile integrated unit. **Circle No. 3**

Seismic Exploration

Termed the "newest recording technique for seismic exploration," the *Ampex Corp.* model 700 seismic drum recorder handles 24 channels of data in frequency-modulated form on a single tape. One major oil company has already purchased four of the units whose playback is said to be "near perfect facsimile of original geophone signals." **Circle No. 4**

Jet Pulverizing

Details of a jet pulverizer built by *Majac Inc.* and of the custom pulverizing service offered by the company have been released. Wide application in the coal and nonmetallics fields are suggested for these air powered pulverizers which are especially intended for producing –200 mesh product. **Circle No. 5**

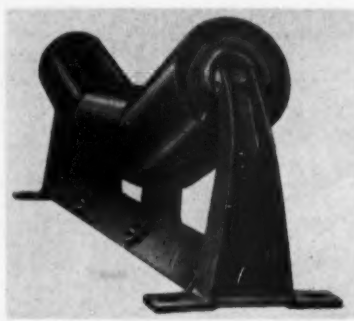
Micron Range Mill

Hyswing ballmill, developed in Western Germany and being distributed in the U. S. by the *Wiwoco Corp.*, offers unique centrifugal action for grinding to finest particle

sizes. Mills carry four 5-liter containers or four 50-liter containers per batch. Carbides have been reported ground to 0.3 micron, and use of mills for ceramics, nonmetallics, and laboratory ore dressing work is suggested by supplier. **Circle No. 6**

Balanced Idlers

Jeffrey Mfg. Co.'s latest MD and HD series belt conveyor idlers incorporates variety of advances. Major



feature of recently introduced line, the Duoflex seal, designed to keep dirt out and keep grease in, results in permanently lubricated idler. Rolls may be removed without loosening or removing stands, and the stands themselves are available with 2° tilted ends. **Circle No. 7**

Torque Drive Excavator

Torque converter-engine combinations now available as optional equipment on certain *Bucyrus-Erie* excavators have been designed to provide a maximum torque of 200 to 225 pct over full load torque for comparable straight friction drive excavators. Units have carefully matched converter-engine units. High speed engines to permit use of high speed torque converters for better efficiency and lowered weight, size, and cost. Smooth, steady power is claimed to yield better results over entire digging cycle, while cushioning effect of converter protects machinery from shock loads and adds to equipment life. **Circle No. 8**

Tough Hose

Flexsteel air hose, added to the *Goodyear Tire & Rubber Co.* line, is a mandrel-made hose with inner heat and oil resistant tube and an abrasive resistant cover reinforced with steel wire to combat abusive mine conditions. Hose has had extensive field testing. **Circle No. 9**

Off-Highway Trucks

Latest end dump 20-ton model from *Dart Truck Co.* has outstanding ma-

neuverability due to 120-in. wheelbase and high power from 225 or 275-hp diesel engine. Other models in the series are the 10-ton and 35-ton units. **Circle No. 10**

News & Notes

As part of its celebration of "50 Years on Tracks" *Caterpillar* held opening ceremonies for its York, Pa., parts operation designed to better serve the eastern states . . . *Consolidated Testing Laboratory Inc.* recently opened facilities for chemical, spectrochemical, and metallurgical testing at West Hempstead, N. Y. . . . Stockholders of *Marion Power Shovel Co.* authorized acquisition of controlling interest in the *Osgood Co.* and of its subsidiaries . . . Recently the name of the *Attapulgus Minerals & Chemicals Corp.* was changed to *Minerals & Chemicals Corp. of America.* Flotation and ore dressing business will be carried out by the Minerals Separation Div. . . . *Crane Co.*, largest producer of valves and fittings in the world, has kicked off for its centennial in 1955.

Free Literature

(21) BLAST HOLE DRILL: Described and pictured in a bulletin from *Bucyrus-Erie Co.* is the 50-T, a large hole churn drill. With all steel trussed frame and rigidly braced 46-ft derrick for high stability, the rig can swing heavy tool strings up to 6000 lb, drill 9 to 12-in. diam holes.

(22) OUTSIDE JOB ORDERS: *Hardinge Mfg.* Co., specializing in heavy process machinery for the mining, chemical, stone products, water, sewage, and trade waste fields, has issued a bulletin describing its plants facilities. Emphasized are the advantages of a medium-size manufacturing firm where production routine does not involve cumbersome record systems and interdepartmental red tape, which can cause delay and needless overhead.

(23) PRESTRESSED CONCRETE: "Tensioning Materials for Prestressed Concrete" from *John A. Roebling's Sons Corp.* gives detailed information and charts on characteristic properties of Roebling wire and strand. Among the applications shown are the Barrett-Lick Garage in San Francisco, which used four of the largest prestressed concrete girders ever made, and the Cañas River Bridge in Cuba, longest prestressed concrete span in this hemisphere at time of construction.

(24) SHOVEL ATTACHMENTS: *Schield Bantam Co.* has two specification bulletins on shovel attachments for the model T-35 ⅝-yd, 6-ton truck-mounted Bantam and model C-35 ⅝-yd crawler-mounted shovel crane. Showing typical shovel applications, these bulletins contain specifications, capacities, and information about optional shovel equipment, such as electric dipper trip and rehandling buckets.

(25) CERAMIC COATINGS: *General Ceramics Corp.'s* bulletin describes ceramic coatings and porcelain enamels to combat corrosion, resist abrasion, withstand high temperatures, and offer special dielectric properties.

(26) TRAMP IRON DETECTOR: Made by *Eriez Mfg. Co.*, Magnalarm has a "brain" element known as the ferrometer that measures the permanence change in the magnetic circuit brought about by the tramp iron

accumulation across the magnet's air gap. Once Magnalarm signals its warning by ringing a bell or lighting a light, it cannot be shut off until the magnetic element has been cleaned.

(27) GRAVITY CONCENTRATION: Bulletin No. T1-B3 from *Denver Equipment Co.* explains how tables are used to treat materials subject to gravity concentration. Given are construction details, specifications, and facts about the capacity and operation of concentrating tables as well as their application in the flowsheet.

(28) COAL PRODUCTION: Form D426, a 12-page, two color booklet, shows *Caterpillar* scrapers, track-type tractors, bulldozers, motor graders, and diesel engines in on-the-job operations, discusses the use of this equipment both in pit and opencast coal mining. Also included is an informative section entitled "Standardization Pays Off." (To secure this book in French circle 20.)

(29) HAZARDS & LOST $$$: Bulletin from *Graver Water Conditioning Co.* shows advantages inherent in the treatment of industrial waste waters and process liquors. Schematic drawings, pictures, and a problem-solution-result explanation demonstrate how Graver equipment solves process and cooling water shortages, contamination of streams, and loss of heat and materials.

(30) FLOTATION AIDS: Both Palcotan and Palconate, reactive chemicals derived from redwood bark, have been shown to be effective in depressing calcite in the flotation of fluorspar or scheelite ore. Other commercial potentials of these two organic chemicals are outlined in *Pacific Lumber Co.'s* bulletin.

(31) DRAGLINE BUCKETS: Replacement parts for any make or model of dragline bucket are described in *Electric Steel Foundry Co.'s* new catalog. Also given are maintenance tips, alloy recommendations, and a method to determine correct drag chain length.

(32) PACKAGED AIR COMPRESSOR: *Ingersoll-Rand Co.* has introduced a packaged air compressor in the 75 to 100 hp range that approaches the efficiency and economy of larger, more powerful, slow speed compressors. An opposed-cylinder, balanced design driven by a direct connected, induction motor, the PHE is a two-stage unit for 80 to 125 psi, but other cylinder arrangements are available for higher pressures or for pumping vacuums.

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for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

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61	Students are requested to write direct to the manufacturer.								

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(33) JAW CRUSHERS: *Pioneer Engineering Works Inc.* has a 48-page booklet covering its line of overhead eccentric jaw crushers and 170 series stationary primary crushing plants. Booklet No. 649 lists the advantages of overhead eccentric jaw crushers, describes the principle and design, construction features and parts, operation and application.

(34) UNDERGROUND MINING: "The Right Power for Underground Coal Mining" from *Caterpillar Tractor Co.* discusses the advantage of

using Caterpillar engines and electric sets in mines to balance production against rising costs. Also included is a detailed list of hp and kw ratings.

(35) BUILT TO LAST: First automatic Bartlett-Snow skip hoist, installed in 1907, is still in active service. New bulletin from *C. O. Bartlett & Snow Co.* shows sequence views of operation of skip hoists for handling bulk materials of all kinds, describes hoist engines, sheaves, head frames, counterweights, and lists bucket capacities.

(36) TRACTOR SHOVELS: Payloaders, manufactured by the *Frank G. Hough Co.*, are shown in Form No. 272A at work in plants, pits, and mines, loading trucks, trimming piles, carrying away oversize materials, hauling equipment, and cleaning up ore spillage. Torque converter drives and power steer—standard on most models—as well as multiple speeds forward and in reverse contribute to their speed, ease of handling, and maneuverability.

(37) PIPE MARKERS: —300° TO 300°F: To replace costly painting and stenciling, *W. H. Brady Co.*, manufacturer of self-sticking industrial products, has developed more than 1000 different all-temperature pipe markers. These conform to ASA Standard No. A-13, "Indentification of Piping Systems."

(38) IMPACT BREAKING: Recently introduced by *Kennedy-Van Saun Mfg. & Eng. Corp.*, the Cuber Senior is a dual rotor impact breaker for both primary and secondary breaking of nonabrasive stone and like material. Unit will handle any quarry rock passing the 36x48-in. opening, and capacity up to 350 tph of —3-in. material is indicated.

(39) PANELBOARDS: Planning commercial and industrial circuit-breaker panelboards is discussed in *Westinghouse Electric Corp.'s* 16-page booklet, B-6098. Both user and contractor are shown the advantages of De-ion circuit breakers and of the dead-front breaker panel.

(40) AIR POLLUTION: Available from *Industrial Hygiene Foundation*, Mellon Institute, are two papers on air pollution, "Variables in Monthly Dust Fall Measurements" and "A Low-Cost Sampler for Measurement of Low Concentration of Hydrogen Sulfide."

(41) COATING SYSTEMS: *Carboline Co.* has available field test data on 60 coating systems, applied on rusty steel panels, tested in a chemical plant and scored for appearance, adhesion, creep corrosion, and edge protection. Data enables evaluation of primer and finish coatings for corrosive atmospheres.

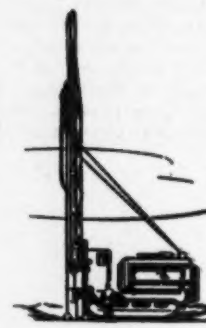
(42) MATERIALS HANDLING: The Alemite Div. of *Stewart-Warner Corp.* has a 32-page catalog of "Versatal" materials handling equipment. These air-operated pumps deliver semisolids and fluids, such as paints, roofing, gear coating, adhesives, putty, direct from container to point-of-application.

(43) RUBBER HOSE & BELTING: Cement placement hose, conveyor belting, dust collector hose, grout hose, hydraulic hose, pile driver hose, welding hose are but a few of the products listed and described in *Carlyle Rubber Co.'s* catalog.

(44) WEEDS: Industrial plants, railroad trestles, railroad yards, storage yards, electrical installations, weeds love them too. *Du Pont's* "Telvar" W weed killer is a wettable powder containing 80 pct 3-(p-chlorophenyl)-1, 1 dimethyl-urea and one application is said to control grass and weeds for one season or longer.

(45) BOTTOM-DUMP HAULERS: The 17-yd bottom-dump catalog, No. 251, from *Euclid* provides information on a unit that features horsepower to weight ratio comparable to rear-dump units. Unit hauls loads of 20 cu yd heaped at 3:1 slope and 25.5 cu yd heaped at 1:1 slope at speeds up to 28.2 mph.

(46) HEAVY DUTY DRILL: *Ingersoll-Rand's* QM-2 Quarrymaster is claimed to be the only machine of its kind developed as a dual purpose blast hole drill for either rotary or percussion drilling. Bulletin depicts



features which include full 40-ft feed, hydraulic leveling jacks, positive power feed, and all weather cab. Quick setups and easy portability are advantages of self-contained and self-propelled units.

(47) CONCENTRATOR TABLE: For *Deister Concentrator Co.'s* bulletin 118-B, described on p. 845.

(48) GYRATORY CRUSHERS: *Traylor Engineering & Mfg. Co.'s* bulletin 126, see p. 753.

(49) DUST COLLECTORS: *Northern Blower Co.'s* bulletin 163-5, see p. 779.

(50) FEEDERS: *Stephens-Adamson Mfg. Co.'s* bulletin 54, see p. 780A.

(51) AIR LEG DRILL: For bulletin RD-30 from Cleveland Rock Drill Div., *Le Roi Co.*, see p. 757.

(52) CHAIN AND CONVEYOR CATALOG: Bulletin 513 from *Wilmot Engineering Co.*, see p. 843. Circle 53 for bulletin 512.

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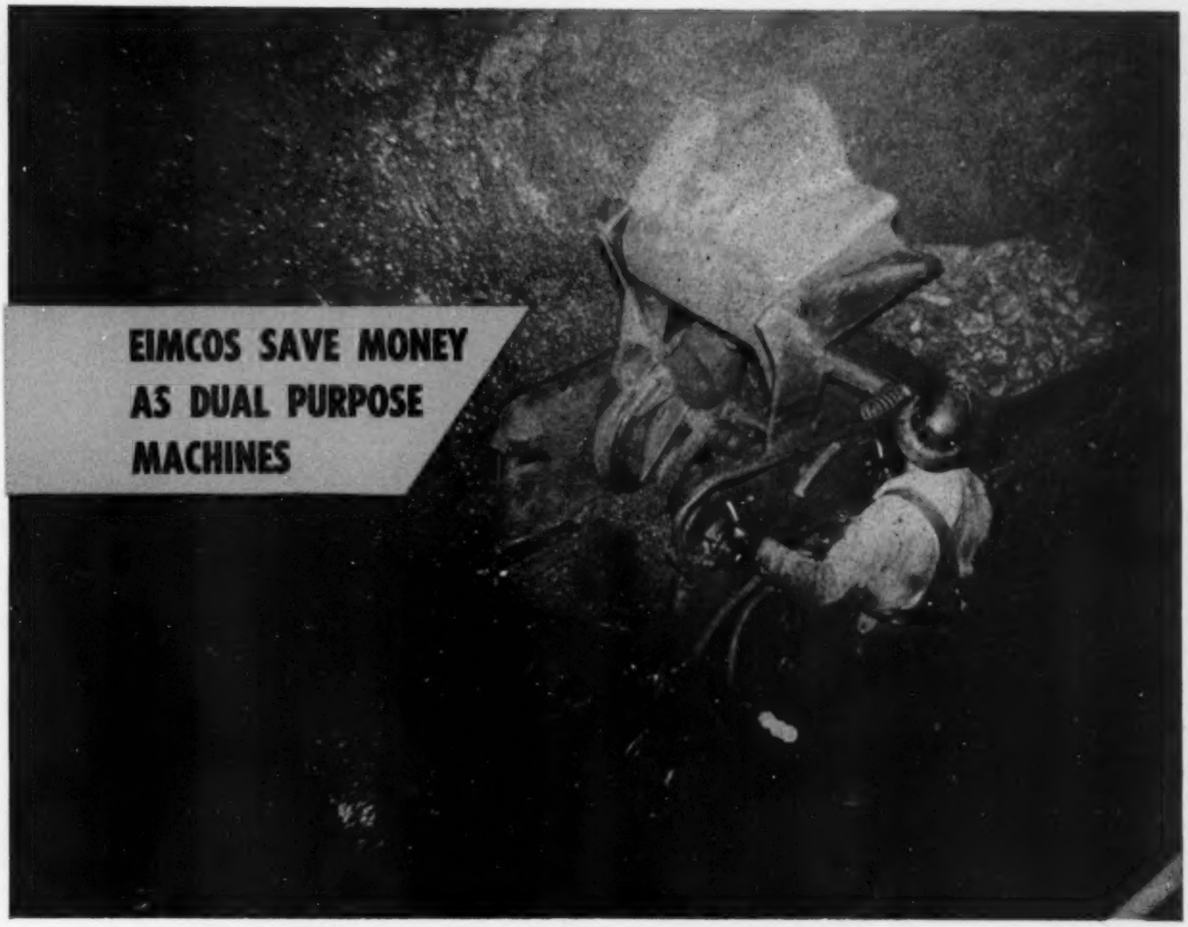

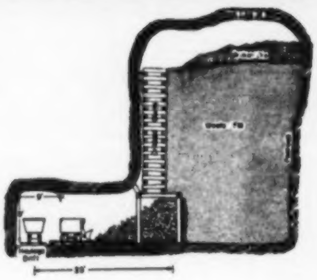

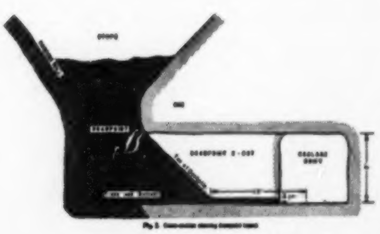

Eimco Loaders are being used for production as well as development work. This dual application for loading equipment has been advanced by numerous large companies who are now mining by drawhole systems including block caving, cut and fill or shrinkage when ore bodies stand more or less upright and even in scraper applications where the ore bodies slope too little to run freely. The idea being to scrape or shoot the ore so that it falls to a station at haulage level where it can be quickly loaded by an Eimco RockerShovel.

These sketches show two examples of methods in use to bring broken ore to haulage level at a minimum cost and provide a place to load mechanically. Many other systems are in use and Eimco Engineers will be glad to advise on layouts that might fit your needs.

THE EIMCO CORPORATION

Salt Lake City, Utah—U.S.A. • Export Offices: Eimco Bldg., 52 South St., New York City

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You Can't Beat An Eimco

WHEN PIPELINES CROSS WATER

explosives research pays off

The tremendous power of dynamite, skillfully and ingeniously handled, made it economically possible to cross the wide, deep Tennessee River (inset above) with two parallel pipelines, 50 feet apart. Trenches blasted underwater through hard red clay in the shallows, and lime rock in the 40-foot-deep channel, opened the way for speedy dredging operations . . . another example of the efficiency of modern explosives and blasting methods.

Hercules' research in the pioneering and development of explosives and our extensive service facilities are available to help you in solving blasting problems on construction jobs or in mining and quarrying operations.

Explosives Department

HERCULES POWDER COMPANY

INCORPORATED

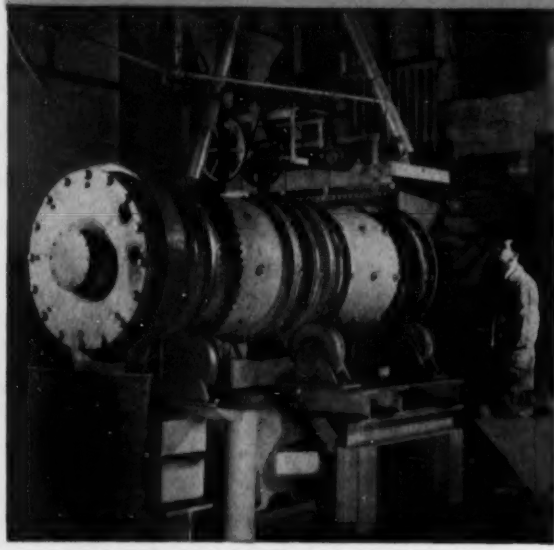
955 King St., Wilmington 99, Del.

Birmingham, Ala.; Chicago, Ill.; Duluth, Minn.; Hazleton, Pa.; Joplin, Mo.; Los Angeles, Cal.; New York, N. Y.; Pittsburgh, Pa.; Salt Lake City, Utah; San Francisco, Cal.

XR54-6

View shows two of several 7' Symons Super Heavy Duty Short Head Cone Crushers installed in the Lake Superior region.

Here's How Industry's Top



Precision tests in the Allis-Chalmers research laboratory determine grinding characteristics and power requirements—accurately predict full-scale performance.

helped increase

smelting capacity

at the BUNKER HILL & SULLIVAN MINING AND CONCENTRATING CO. Kellogg, Idaho

IN lead smelting, Bunker Hill & Sullivan uses a charge for their roasters made up of limestone, reclaimed slag, lead concentrates and circulating by-products. Realizing that a uniform and porous charge would increase roaster capacity and produce an improved sinter, Bunker Hill & Sullivan decided to pelletize the roaster charge. In order to achieve a uniform mixture and control the pellet size, it was necessary that all materials be crushed to minus ¼ inch, with the bulk of the materials minus 10 mesh. The main charge ingredients requiring crushing consisted of limestone, reclaimed slag and return sinter. Allis-Chalmers was asked to help with this problem.

Here's what Allis-Chalmers did:

Lab Tests The Allis-Chalmers lab team went to work on samples of these three materials. Impact and compression tests were made to determine crushing resistance. Grinding characteristics were established in rod mill grindability tests. Slag was found to be the ingredient most resistant to crushing. The tests also helped determine type and size of equipment needed and power requirements. All this vital information was obtained easily and at little cost.

Pilot Plant Run Because an unusually large dry grinding rod mill had been indicated by the lab tests — and to reveal any factors which may have remained hidden in tests on small samples — twenty tons of slag were run in the Allis-Chalmers pilot plant. Evaluation of all test findings by specialized engineers indicated the application of a *Low-Head* screen, *Hydrocone* gyratory crusher and an Allis-Chalmers dry grinding peripheral discharge rod mill for this crushing problem. The equipment is now operating in the Bunker Hill & Sullivan plant where it produces the required finely crushed material for production of pellets.

Help for Your Staff or Consultants The same personal, expert attention is available to you. Your A-C representative, backed by industry's top technical team, is always ready to help you make your operation as efficient and profitable as possible — whether it's a matter of planning a complete plant or merely helping you over an occasional rough spot.

Continuous Service Most important is the fact that Allis-Chalmers interest does not terminate with the installation of equipment. Laboratory facilities, periodic equipment checkup, maintenance, and fast emergency parts service are yours continuously from Allis-Chalmers.

ALLIS-

Technical Team

In the Bunker Hill & Sullivan operation, a 48-in. Hydrocone crusher preceded by an Allis-Chalmers rod deck screen produces a minus ¾-in. feed for the 9 x 12 Allis-Chalmers dry grinding peripheral discharge rod mill which delivers a minus 10 mesh product for pelletizing.

Low-Head and Hydrocone are Allis-Chalmers trademarks.

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Crushers — all types
Vibrating Screens — all types — Grinding Mills — all types
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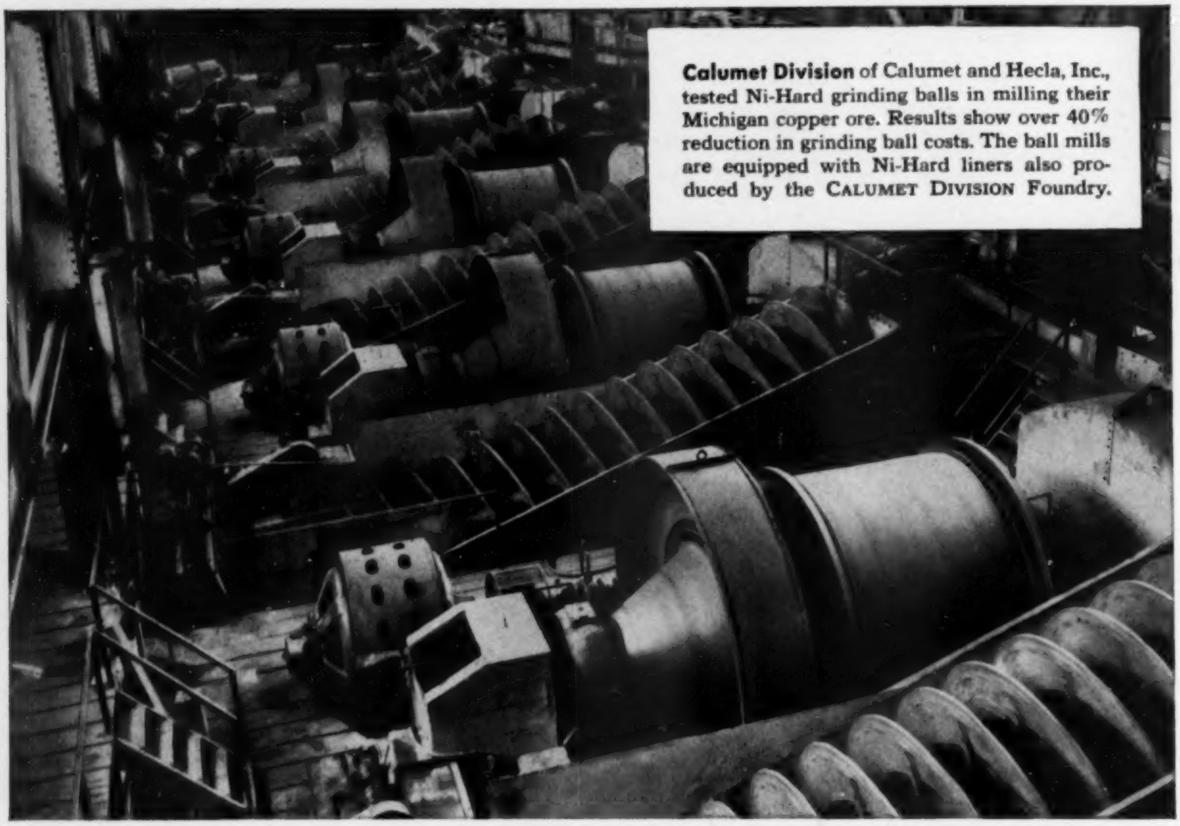
For complete information, call your nearest A-C district office or write Allis-Chalmers, Milwaukee 1, Wis.



Calumet Division of Calumet and Hecla, Inc., tested Ni-Hard grinding balls in milling their Michigan copper ore. Results show over 40% reduction in grinding ball costs. The ball mills are equipped with Ni-Hard liners also produced by the CALUMET DIVISION Foundry.

CALUMET DIVISION Reports Ni-Hard Grinding Balls Provide

75% Greater Resistance to Wear

than Forged Alloy Steel

EVERY DAY these six ball mills grind about 500 tons of copper ore for the CALUMET DIVISION of Calumet and Hecla, Inc., Calumet, Michigan.

Ni-Hard grinding balls produced by the CALUMET DIVISION Foundry were used in comparative tests conducted in this battery of 8′ x 6′ conical mills. The test was designed to get to the meat of the problem . . . *the actual cost of grinding balls used per ton of ore ground.* When compared to forged steel and alloyed steel balls Calumet Ni-Hard grinding balls showed a cost reduction of over 40%.

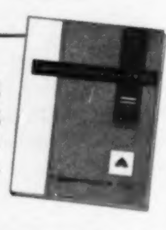
Feed to these mills is amygdaloid copper ore. Feed size is minus 1/4″, and product size is minus 28 mesh, with about 50% through 200 mesh. Several sizing tests indicate an 8 to 10% increase obtained through 200 mesh by using Ni-Hard balls.

Wear ratios for a 10-month period are:

Forged steel	.53 lbs. per ton
NI-HARD	.30 lbs. per ton

It's easy to see how this superiority of 1.75 to 1 can help keep overhead down. To learn how Ni-Hard can be of help to you, write for "Engineering Properties and Applications of Ni-Hard." It's yours for the asking and the information it contains will certainly be of interest.

The completely revised third edition of "Engineering Properties and Applications of Ni-Hard" is now available. Write for your copy today.



EMBLEM OF INCO SERVICE

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N.Y.

NEW JERSEY ZINC Co. has signed agreements with Big Game Mines Ltd., Gui-Por Uranium Mines & Metals Ltd., Moon Lake Uranium Mines Ltd., and Calder-Bousquet Gold Mines Ltd. under which it may acquire majority control of those firms. For a one to two-year period New Jersey Zinc will investigate uranium potential of holdings of these companies in the Blind River district north of Lake Huron, about midway between Sudbury and Sault Ste. Marie.

IDAHO MARYLAND MINES CORP. has negotiated a lease agreement for uranium claims in the Moab district of Utah. Names of the lessors of the 1165 acres were not disclosed. Geophysical work has begun and drilling is to start shortly. Payment to the lessors will be on a royalty basis, with no cash involved in the present transaction. Bert C. Austin, president of Idaho Maryland, stated that Geiger counter and geological exploration have been sufficiently satisfactory to justify drilling.

NATIONAL GYPSUM Co. plans to have its Nova Scotia gypsum deposits, about 30 miles from Halifax, in production by spring 1955. The development will cost an estimated $6 million and is expected to supply the company's four Atlantic Seaboard plants for at least 200 years. Ship loading and handling equipment is now under construction near Halifax.

BRITAIN'S NATIONAL COAL BOARD is planning a unique experiment involving drilling for coal at sea. The first holes will go down from platforms off the coast of Fife, Scotland. Platforms will be similar to those used for wartime seaforts. They will be floated out and established for each borehole, and when boring is completed, refloated and towed to other locations. The boring tower will be designed for any depth up to 20 fathoms and for drilling up to 3½ miles offshore.

Edmund F. Mansure, head of General Services Administration, announced the Government's intention to purchase 200,000 flasks of domestic and Mexican mercury at $225 per flask during the next three and one half years. About 75,000 flasks will come from south of the border. While the Government price is well below current world prices it is more than the average for recent years. It is reported that many small California operations are contemplating reopening. About a dozen significant mines were in operation in the state when the announcement was made.

Iron Ore Co. of Canada saw the first trainload of 60 cars of iron ore pull into Sept Iles recently, three years after operations in Labrador began. The mine at Knob Lake, the railroad, and the Sept Iles port cost the company some $250 million. Most of the ore is bound for the M. A. Hanna Co. steel plants. First ship loadings were expected to begin in late July.

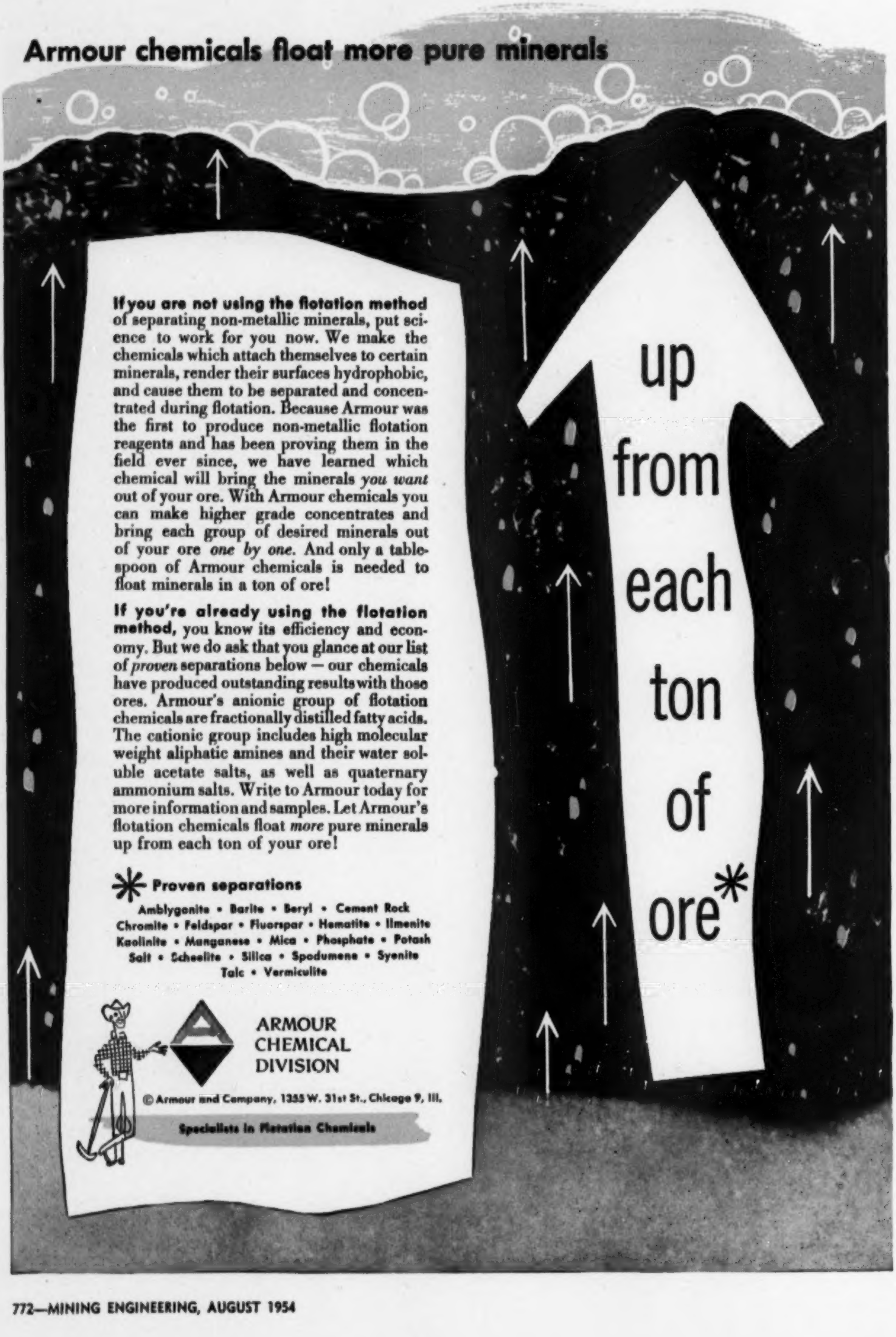
LEHIGH COAL & NAVIGATION Co. closed its Panther Valley anthracite operations after unsatisfactory contract negotiations during which the company demanded that the union live up to the letter of the old agreement. Lehigh told the union that the only way the mines could survive is for workers to turn out increased tonnages. After protracted negotiations Lehigh decided to cease production.

TEXAS GULF SULPHUR Co. ran off with top honors for management excellence among mining firms in a recent survey. The company was named by the American Institute of Management in its first announcement of the management leaders of respective industries. Announcement came in the AIM report series, *The Corporate Director*. The Institute contends, "The quality of management can be gaged with such close accuracy that most of the risk factors in the purchase of securities can be minimized and, at times, almost wholly eliminated."

Slump in the ore markets has hit India, with most of the manganese and iron mines in the Singhbhum district of Bihar State closed. More than 60 of 200 manganese mines in Madhya Pradesh, which account for 70 pct of Indian ore exports, have closed during the last five months. The slump is blamed on the entry of the Philippines into world iron ore market and the Russians into the world manganese market.

STAMFORD, CONN., has been selected by Horizons Titanium Corp. as the site for a new titanium metal pilot plant. Size of the plant has not been disclosed. The Government has allocated approximately $564,000 for the project.

SEPTEMBER 1 HAS been named as the date for starting production at Standard Uranium Corp.'s Utah mining properties. According to Joseph W. Frazer, president of Standard Uranium, production will be about 600 tpd by the end of the year. Mr. Frazer also announced that his company is making a payment of $450,000 toward outright purchase of the 15 mining claims comprising its property in San Juan County near Moab, Utah.


Armour chemicals float more pure minerals
up from each ton of ore*
If you are not using the flotation method of separating non-metallic minerals, put science to work for you now. We make the chemicals which attach themselves to certain minerals, render their surfaces hydrophobic, and cause them to be separated and concentrated during flotation. Because Armour was the first to produce non-metallic flotation reagents and has been proving them in the field ever since, we have learned which chemical will bring the minerals you want out of your ore. With Armour chemicals you can make higher grade concentrates and bring each group of desired minerals out of your ore one by one. And only a tablespoon of Armour chemicals is needed to float minerals in a ton of ore!
If you're already using the flotation method, you know its efficiency and economy. But we do ask that you glance at our list of proven separations below — our chemicals have produced outstanding results with those ores. Armour's anionic group of flotation chemicals are fractionally distilled fatty acids. The cationic group includes high molecular weight aliphatic amines and their water soluble acetate salts, as well as quaternary ammonium salts. Write to Armour today for more information and samples. Let Armour's flotation chemicals float more pure minerals up from each ton of your ore!
* Proven separations
Amblygonite • Barite • Beryl • Cement Rock
Chromite • Feldspar • Fluorspar • Hematite • Ilmenite
Kaolinite • Manganese • Mica • Phosphate • Potash
Salt • Scheelite • Silica • Spodumene • Syenite
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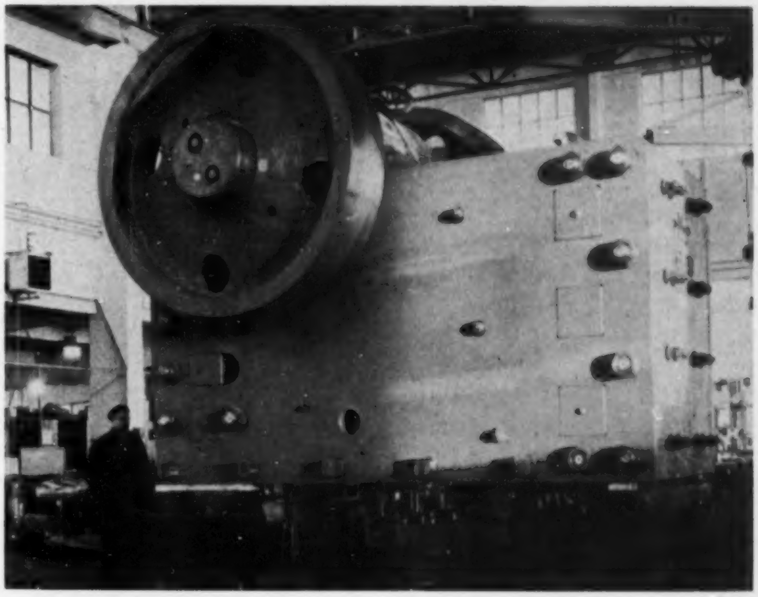
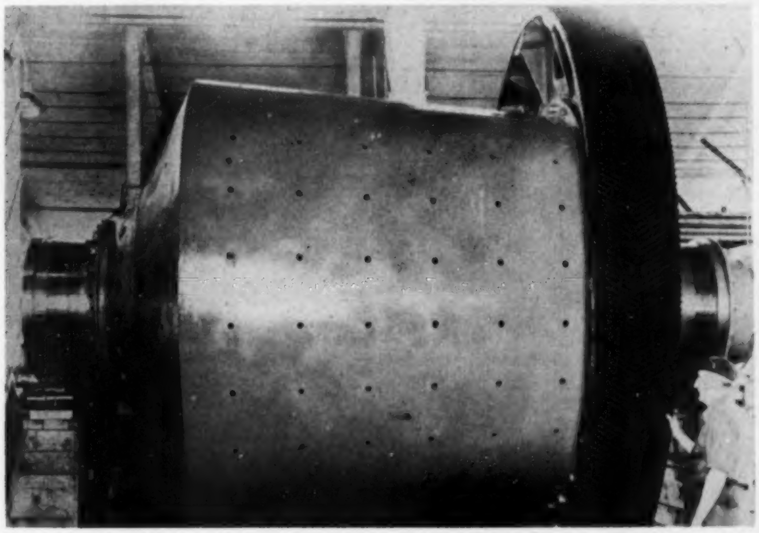
ARMOUR CHEMICAL DIVISION
© Armour and Company, 1355 W. 31st St., Chicago 9, Ill.
Specialists in Flotation Chemicals

Big Machines Make Mining News of the Month

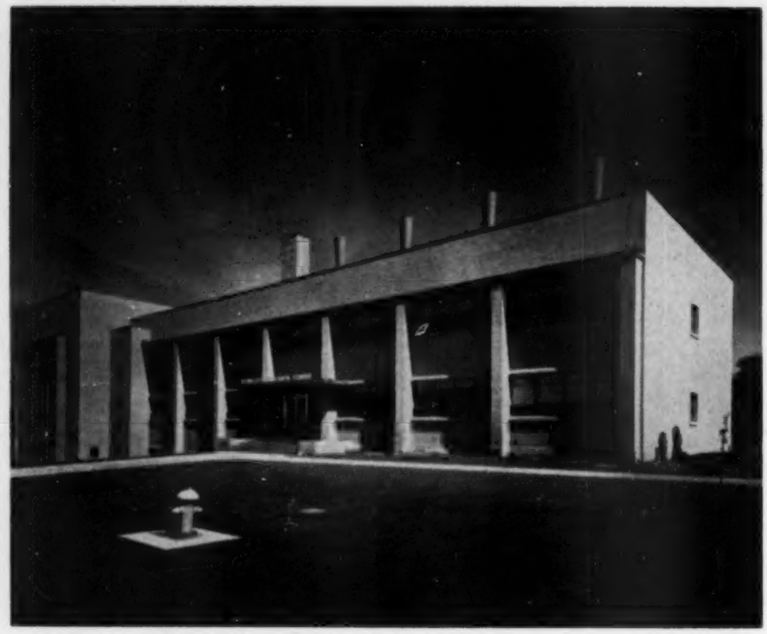
According to the Polish Embassy, Poland's coal mines are going in for mechanization in a big way. The country reports its coal output is increasing and will match the mark set by the current Five-Year Plan. This combine is one of the newer pieces of equipment behind the Iron Curtain.





LEFT: Second Tricone for Tennessee Copper Co. was recently shipped to Copper Hill, Tenn., by the builders, Hardinge Co. First tricone at Tennessee Copper Co. plant had 11-ft diam. New mill has 10½-ft diam at feed end. The 9-ft long mill tapers to 9-ft diam at the discharge end. ABOVE: Lapland is getting five of these huge crushers for installation underground at the famous Kiruna and Malmberget mines of Loussavaara-Kirunavaara AB. The 71x55-in. crushers weigh 116 tons and handle pieces weighing up to 10 tons. Largest SKF bearings ever mounted in a jaw crusher were utilized by Swedish designers, Morgardshammars Mek. Verkstad.

This giant amphibious motor vehicle riding 6 ft off the ground may some day play a big role in swamps and desert exploration. The 10-ft diam tires built by Goodyear Tire & Rubber Co. are among the largest ever made. Constructed for military testing by the Army, the vehicle is an adaptation of Gulf Oil Corp.'s Marsh Buggy.



New Kennecott

Ultramodern Setup At University of Utah

Early this month Kennecott Copper Corp.'s new research center on the campus of the University of Utah will be dedicated. Built and equipped at a cost of $1.25 million, the building houses the most modern pilot plant and laboratory facilities available.

A MAJOR step in the development of metallurgical science will take place August 13 on University of Utah's campus, Salt Lake City.

On that date Kennecott Copper Corp. will officially dedicate its ultramodern $1.25 million Research Center as a central facility coordinating and handling expanded research programs for the corporation's Western Mining Div. operations in Arizona, New Mexico, Nevada, and Utah.

Dedication ceremonies for the new Research Center will be part of a celebration observing the 50th anniversary of the corporation's Utah Copper Div.

According to Research Center officials, the primary importance of the center is "to study problems and improve methods used in our mining, milling, and refining operations and to develop the results into commercial application."

Research Center officials point out that whereas in past years Kennecott has conducted research on specific problems at each of its divisions, now these studies will be coordinated through the Research Center and results applied to specific problems at an accelerated pace.

As such, the Research Center represents a major step in a continuing program of Kennecott to obtain maximum efficiency designed to extend the life of its properties.

Commenting on the importance of the new Center, E. S. Hann, Kennecott's treasurer, said recently:

"This modern laboratory, with up-to-the-minute research facilities, including pilot plants, is one of the most important and far-reaching projects undertaken by the company in recent years, and should prove to be an invaluable asset in our endeavor to recover additional metal from the ores mined."

Built primarily of concrete, brick and steel, the 3-story structure of functional design, incorporates 40,000 sq ft of space, with pilot plant facilities using some 12 pct of the area and laboratories and offices occupying the remainder.

Tinted glass, fluorescent lighting, individual room ventilation and temperature are laboratory features, along with use of glazed ceramic tile walls, asphalt tile or cement floors, and transite ceilings.

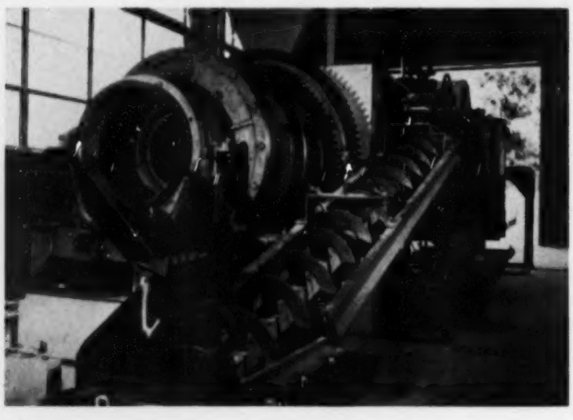
To prevent pilot plant vibration from affecting the sensitive laboratory apparatus, laboratory sections of the structure are separated from plant installations by an expansion joint through the entire building.

Laboratories are equipped to study all types of metallurgical problems and fundamental research. The ore dressing section and the units devoted to hydrometallurgical and pyrometallurgical investigations are said to be the most modern and complete in the industry.

Installations in the laboratories include an X-ray diffraction unit with fluoroscopic attachment, a 3.4-m emission spectrograph, and infra-red absorption spectrophotometer for physical analysis. In addition to such equipment destined for studying the structure and composition of ores and metallurgical products, complete chemical laboratory facilities are provided.

The pilot plant, complete with latest equipment, has many additional service features recognized as making it the last word in modern pilot plant operation. The plant has a 5-ton capacity overhead traveling crane; high and low pressure steam; and a choice of 110-v, 220-v single phase, and 220-v 3-phase power available at easily accessible outlets. The pilot flotation mill is designed to handle 600 lb of ore per hr.

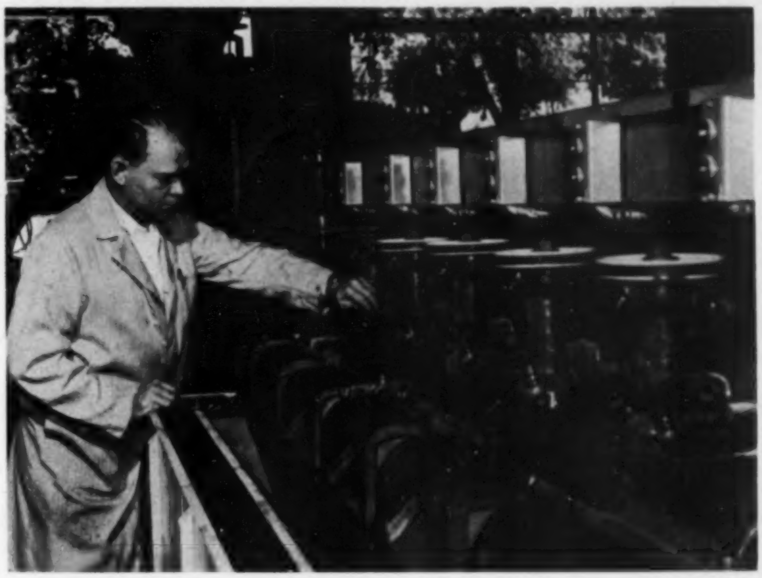
Projects already underway at the center deal with improved recovery



The ¾-ton capacity ball mill at left in pilot plant is shown with ore classifier, center, feeding bin, thickener tank and filter in back. Pilot plant is designed to treat 600 lb per hr of low grade ore.

Research Center to Coordinate Work of Western Mine Divisions

One of the several banks of flotation cells is inspected by Arthur W. Last, center's pilot plant head. The V-shaped bin in the left background feeds ore into ball mill.



of copper and other metals by leaching. Pilot plant testing of improved techniques in extractive metallurgy resulting from laboratory work will begin with the arrival of still more equipment. In addition to studies of better recovery of ores from present waste minerals of the Utah operations, studies are underway on the flotation processes used in Kennecott's mills in the Southwest.

New flotation reagents are under examination along with studies of the feasibility of leaching unrecovered copper from present tailings, while scouring of oxide minerals from sulphide minerals to improve overall copper recovery is likewise under study.

Other steps in Kennecott's continuing program to obtain maximum efficiency of operation and to extend the life of its properties, have been:

(1) Construction of an electrolytic refinery in Garfield, Utah, at the cost of about $17 million.

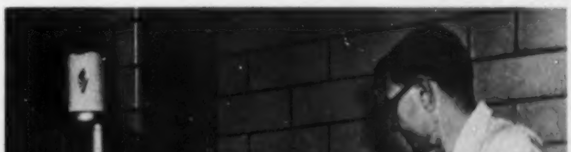
(2) Development of additional ore in the area of the mine in Ruth, Nev., which brought the Kimbley open pit into production in 1953.

(3) Complete conversion of the Ray underground mine at Ray, Ariz., to open pit operation, which will result in a more economical and longer-lasting operation.

(4) Extension of the mining area of the Chino Mines Div. in Santa Rita, N. M., to develop additional ore reserves and to continue satisfactory mining operations. This extension is nearing completion and has necessitated removal to new locations of houses, shops, stores, offices, and other buildings situated over some of the new reserves.

These improvements in the operations of the existing Western Mining Div. properties indicate the large scope of production problems and activity, particularly regarding porphyritic ore mining with which the new Research Center must deal.

The pilot plant occupies 12 pct of the entire structure's 40,000 sq ft floor space. At right rear are experimental leaching columns and at extreme right is drum type media separator. Equipment was selected to meet any ore concentration research problem.



Mineral concentrations as small as 0.01 to 0.0001 pct can be determined with the comparative spectrograph being operated by Ralph Wood. The center is equipped with the last word in modern research tools.

. . . there are several starting points for its many uses and users

"What shall we use?" This question always confronts management when it is considering raw materials to be used in operating processes, and is not always easy to decide.

In the manufacture of sulphuric acid, the use of sulphur in some form is mandatory, whether it be elemental sulphur or sulphur in combination with other elements. No single factor can determine which raw material should be used. Relative supply situation, cost of transportation, cost of plant and cost of use are all considered by management.

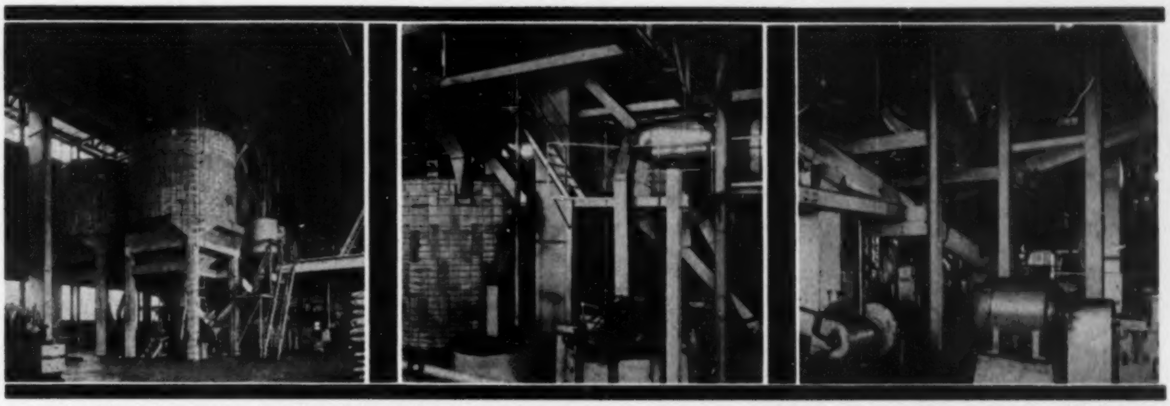
For three decades elemental sulphur as a raw material has had first choice as a solution of the problem, "What shall we use?"

Texas Gulf Sulphur Co.

75 East 45th Street, New York 17, N. Y.

Sulphur Producing Units

- **NEWGULF, TEXAS**
- **MOSS BLUFF, TEXAS**
- **SPINDLETOP, TEXAS**
- **WORLAND, WYOMING**



Interior (a) of the new Austin-designed Penn Rillton plant shows compact equipment arrangement to permit future expansion. Warehouse is at lower right rear. Raw materials pass up bucket elevator at left, through screw conveyors and then to silos. Double-deck Link-Belt vibrating screens (b), totally enclosed and dust-tight, are at left in rear center. Centrifugal separator is in lower center, topped by motor and belt drive. Screw conveyor (c) runs up at angle from storage bin at upper left and connects sea coal line to pitch line for blending. Another conveyor, just above it, running to right, feeds back oversize to sea coal pulverizers. Roller chain drive in lower left is dust and oil tight.

This Processing Plant is Packed Tight for Maximum Efficiency

At West Elizabeth, Pa., on the Monongahela River, the Penn-Rillton Co. has built a plant described as "one of the most concentrated and completely automatic installations of materials handling and processing equipment ever packed into an area of comparable size."

The plant manufactures fine pulverized foundry mold facing and core binder materials from lump coal and coal tar pitch. With an intricate maze of pulverizing, conveying, and blending equipment, and two 100-ton storage silos concentrated in 2400 sq ft of floor space, there is still lots of room for expansion in the 7400-sq ft manufacturing area. The present setup has an initial daily output of 140 tons of bagged and finished products.

Interlocking automatic controls, explosion-proof motors and electric equipment, and an all-inclusive dust control and collection system were designed by the Austin Co. According to Austin officials, the dust control and collection system sets new standards.

Raw materials are unloaded into hopper on north side of the plant, viewed here from the southwest. High section of the building is the manufacturing area. Brick-faced one-story section houses offices and locker facilities, boiler and electric control center. Loading platform for finished products in on south side.

Maintenance and production personnel are limited almost entirely to men required to operate bagging machines and to handle finished product to and from storage or shipping platform. Raw material comes from nearby mines and is unloaded directly into the car hopper on the north side of the building. A belt conveyor transports lump coal and dry coal tar pitch from the car hopper to a single roll crusher, from which they go to the top of the building by bucket elevator. Passing through screw conveyors, the coal and pitch are delivered to respective silos. In the processing routine they pass through any of a number of combinations of pulverizers, screens, separators, and other equipment, and are reduced to —200 mesh or finer before arriving at bagging machines on the main floor. Desired composition and grain size dictate combination of equipment used to treat the raw material. Coal and pitch are sometimes combined in various proportions.

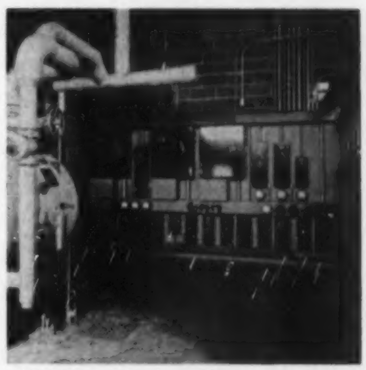
Core blenders with special properties are achieved by mixing pitch with goulac, clay, dextrine, and other substances.

The building is so located that it may be extended in two directions. Present manufacturing area measures 100x74 ft, with a clear area of 40 ft from the floor to the base of the trusses. Only 2400 sq ft of floor space is needed for the two 100-ton silos, including related equipment. Room is available for six more silos of the same size.

The entire conveying and processing installation is completely enclosed and dust-tight. A negative pressure is maintained in the system by dust collection equipment, with one collector for pitch dust and one for sea coal dust. Collectors may be operated in combination or separately.

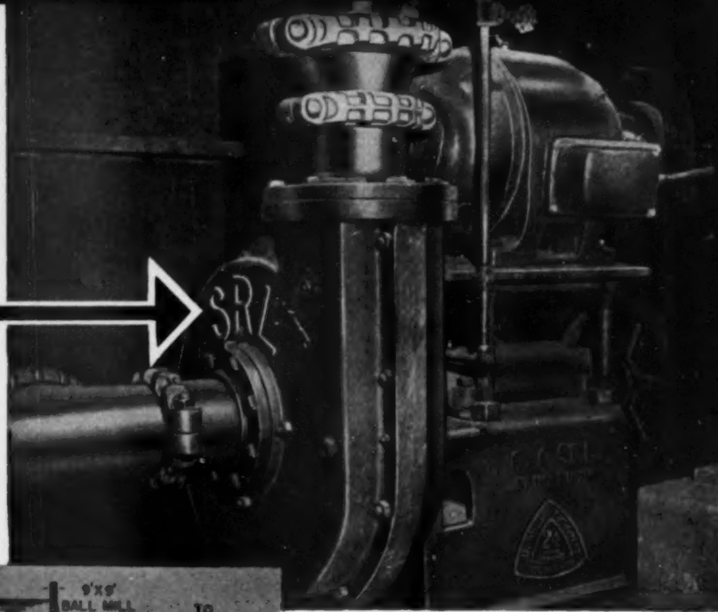
Selection of proper drives permitted the use of identical 75-hp, 1800-rpm, explosion-proof motors to power the pitch pulverizer, operating at 1800 rpm, and two coal pulverizers, operating respectively at 1200 and 3600 rpm. Thus only one spare motor, instead of three, must be kept on hand.

There are six 70-ft H section trusses that top the manufacturing area. The 20-ft space between them is utilized for some of the processing equipment above the silos. Office and other facilities are housed in a one-story wing. Rail lines bracket the plant, with incoming raw materials brought in on the north side, and finished products leaving the loading platform on the south side.

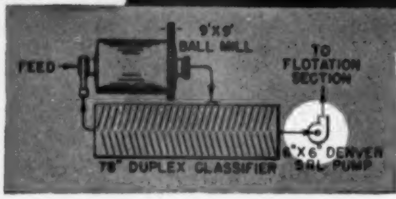


Electric motor controls and metering equipment are centralized and interlocked. White dials are ammeters. Costs were cut by locating starters in the boiler room, thus eliminating need for making them explosion-proof. All electrical equipment in the manufacturing and warehouse areas is explosion-proof.

DENVER SRL PUMPS AT Climax



Here's why Climax Molybdenum Company has 44 Denver SRL Sand Pumps in it's modern, efficient mill



A 6"x6" Denver SRL Sand Pump operating at 690 r.p.m., handling 2200 tons per 24 hours of —28 mesh classifier overflow material at 45% solids. Life of pump runner and casing liner was 593,000 tons.

BACKGROUND

Originally, a 2"x2" Denver SRL (Rubber Lined) Sand Pump was installed on a trial basis at Climax to handle coarse, abrasive —28 mesh deslimed pyrite flotation concentrates. Later, Climax purchased one 6"x6" Denver SRL Pump to handle the problem described with the photo above.

RESULT

Operation of these original Denver SRL pumps was so successful that, as a direct result, 42 additional Denver SRL Sand Pumps have been installed in this outstanding mill. These new pumps vary in size from the 2"x2" SRL (Open Runner) to the 8"x6" SRL-C (Closed Runner).

REASON

The Climax operators have found the efficient, trouble-free operation of Denver SRL Pumps entirely satisfactory. Life of wearing parts is long and shut-down time minimized. Horsepower requirements have been low and high efficiencies have resulted. Obviously, the Denver SRL is a big success at Climax.

HOW DENVER SRL PUMPS CAN REDUCE YOUR PUMPING COSTS

Send full data to us today regarding your particular pumping problem. Experienced DECO engineers will evaluate your problem and will return correct and workable recommendations immediately. This will obligate you in no way.

We carry replacement parts for all sizes of Denver SRL Sand Pumps in our Denver stocks. This enables us to give you prompt service whenever you may need it.

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DECO FLOTATION ENGINEERS — DENVER EQUIPMENT COMPANY — 24 HOUR SERVICE

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DENVER EQUIPMENT CO., 1400 Seventeenth St., Denver 17, Colorado

Chamber Appoints Resources Committee

The U. S. Chamber of Commerce announced its 1954-55 Committee on Natural Resources. The 44-member group has a balanced representation of the extractive natural resources industries and related fields of energy supply, conservation, and land utilization from all sections of the U. S.

Mining is represented by the following men:

Minerals and Metals—Frank E. McCaslin, president, Oregon Portland Cement Co., Portland, Ore.; Ralph L. Dickey, president, the Kelley Island Lime & Transport Co., Cleveland; Donald M. Fraser, chief geologist, mining div., Bethlehem Steel Co., Bethlehem; R. C. Klugescheid, vice president and general counsel, Kennecott Copper Corp., New York; H. L. Pierce, president, Hanna Nickel Smelting Co., Cleveland; L. J. Randall, president, Hecla Mining Co., Wallace, Idaho; Walter L. Rice, president, Reynolds Mining Co., Richmond, Va.; Richard A. Young, vice president, American Zinc, Lead & Smelting Co., St. Louis.

Coal—Thomas C. Cheasley, vice president, Sinclair Coal Co., Kansas City; David L. Francis, president, Princess Elkhorn Coal Co., Huntington, W. Va.; George A. Lamb, manager, business surveys, Pittsburgh Consolidation Coal Co., Pittsburgh; A. L. Lynn, vice president, Island Creek Coal Co., Huntington, W. Va.

Plan 2-Mile Conveyor For Diamond Operation

The longest conveyor system in Africa is to be installed at the Williamson diamond mine in Tanganyika, East Africa. The system was designed by Hewitt-Robins Inc. and will carry diamond ore at the rate of 300 tph from mine to processing plant, 2 miles away.

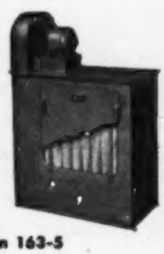
Aided by the new conveyor system and processing plant, production four times the present output is expected at Williamson. The conveyor will replace 15-ton trucks now used. Serious interruptions in production were caused by vehicles bogging down in mud.

Discovered in 1940 by John Thorburn Williamson, a Canadian geologist, the diamond deposit is said to be potentially the richest in the world. Current production is estimated at $24 million per year, about 12 pct of the world total.

The conveyor system was designed by a Hewitt-Robins subsidiary, Robins Conveyors S.A. Ltd., Johannesburg, South Africa, and is being built in a Johannesburg plant.

Buy Guaranteed Efficiency in your Dust Collection... Consult Norblo

Guaranteed efficiency of fume and dust collection systems engineered and built by Norblo is obtainable because Norblo Equipment includes automatic bag type, improved centrifugal, and hydraulic types. Your operations may require one of these types — or all three! Norblo can tell you — will engineer the necessary combination to handle your dust and fume collection at most economical cost. More than 40 years experience serving many industries. State your problem so we can send literature on equipment applicable to your needs.



Norblo Portable Dust Collecting Units solve many localized problems.

Ask for Bulletin 163-5

The Northern Blower Company

Engineered Dust Collection Systems for All Industries

6424 Barberton Ave. OLympic 1-1300 Cleveland 2, Ohio

TWICE THE PRODUCTION — FOR THE SAME $ INVESTMENT

The clay digging job shown in the picture and reported in the adjacent column is being excavated as shown in the sketch above. Successive cuts are taken at an average depth of 6-8 feet with 105's which provides fastest digging with no danger from undercutting.

Digging in clay without the benefit of preliminary ripping or drilling and shooting was the basis of the test between this Eimco 105 and an ordinary front end shovel loader of equal size and price.

Four trucks of the same size, design and manufacture were used. Two were assigned to each loader.

Results — the Eimco 105 could dig the hard clay easily and load quickly with an inexperienced operator at the controls. One day's production — 153 trucks with the Eimco waiting on trucks much of the time.

The ordinary shovel loader had difficulty digging, was slow to maneuver and loaded 75 trucks in the same time with trucks waiting to be loaded all the time.

This customer bought its second Eimco 105 a week after the first was on the job.

Eimcos deliver on all types of jobs and you can have — "Twice the production for the same $ investment" — when you use Eimco 105 tractors with loading attachments.

THE EIMCO CORPORATION

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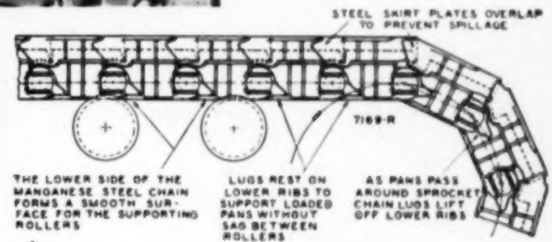
You Can't Beat An Eimco

S-A "AMSCO" MANGANESE FEEDERS

"AMSCO" Feeders withstand the punishing impact and abrasion of ore loads—often falling many feet—through multi-million ton service. One unit logged over 26-million tons in a seven year period, another has handled 65-million tons in 23 years . . . typical examples of outstanding service in both long life and tonnage.

This "AMSCO" secondary feeder discharges to belt conveyor. An S-A Tel-level control automatically stops the feeder if there is a choke-up.



Elevation of S-A "AMSCO" pans and chain showing knee-action lugs at joints. Lugs permit chain to bend freely around sprockets but prevent sagging between track-rollers, even under load. Bottom of chain forms a smooth surface for the track-rollers.

No Matter How Brutal the Beating, They Come Back for More...MUCH LONGER

Because all wearing parts are made of MANGANESE, the toughest steel known to man

Thousands of tons of ore and rock crash down every day . . . and these smashing, loading impacts continue year after year . . . yet S-A "AMSCO" Feeders unfailingly handle high tonnages from car dumps, primary crushers and loading pockets—feeding to or from scalping screens — meeting every application where feeders must absorb heaviest abrasive punishment . . . with practically no maintenance.

Nothing but Manganese steel will withstand these repeated, punishing impacts, this constant abrasive action . . . that's why in S-A "AMSCO" Feeders, pans, chains, pins, bushings, track roller, sprocket — in fact *all components subject to wear* — are made of manganese steel . . . and actually become tougher and more abrasion-resistant with repeated shocks.

S-A "AMSCO" Feeders are individually engineered to provide lowest cost-per-ton handling for heaviest-duty applications. Tremendous in size and capacity, they have a life expectancy rated in millions of tons — as proved by their record in mines since 1908.

An S-A engineer will give you complete information — or wire for our Bulletin No. 54.

SINCE 1901 S-A STEPHENS-ADAMSON MFG. CO.

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Specialists in the design and manufacture of all types of bulk materials conveying systems.

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A complete line of conveyor accessories including centrifugal loaders—car pullers—bin level controls—etc.

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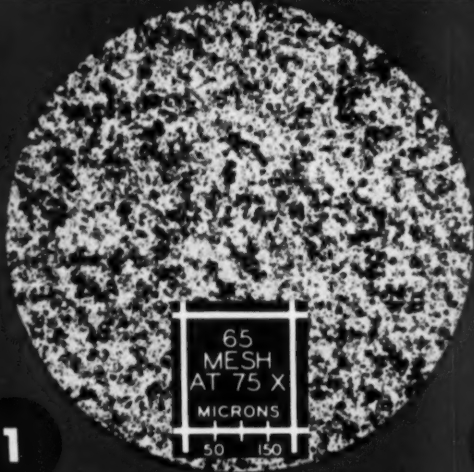
A complete line of industrial ball bearing units available in both standard and special housings.

CAMERA-EYE EVIDENCE OF THE

HIGHLY EFFECTIVE ACTION OF

CYANAMID AEROFLOC® REAGENTS

1



2

For powerful flocculation....

Photomicrographs show tungsten slimes in dispersed form (Fig. 1), and in flocculated form (Fig. 2) after the addition of only 0.08 lb. AEROFLOC per ton of dry solids. On opposite page, Figure 3 shows 10% solids slurries of these slimes in 1000 ml. graduates, with the addition of AEROFLOC 552 at the rate of 0.08 lb. per ton being made at the right.

Figures 4 and 5 (taken one minute and ten minutes later) demonstrate the incredibly fast settling action of the AEROFLOC Reagents.

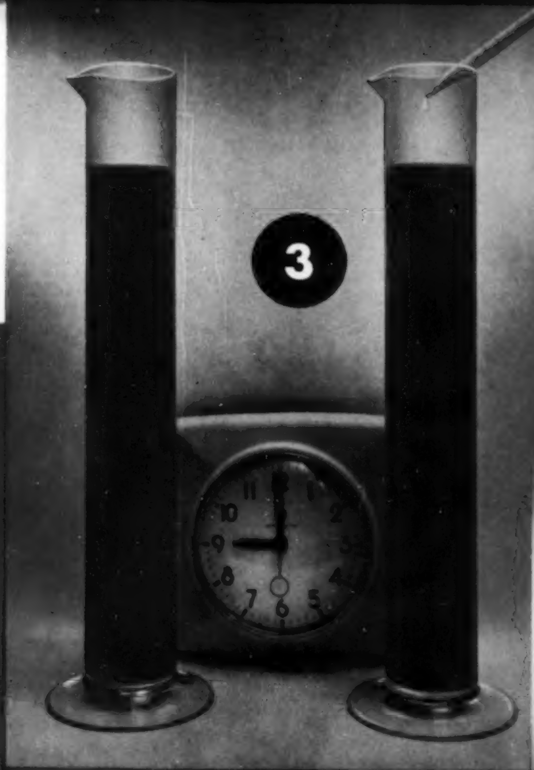
Two Cyanamid AEROFLOC Reagents are in commerical use in plants treating precious-metal, base-metal and non-metallic ores and coal. AEROFLOC Reagents speed-up and effect more complete settling of both valuable concentrates and plant tailings, thereby conserving values previously lost to thickener overflow or reducing solids content of plant effluents.

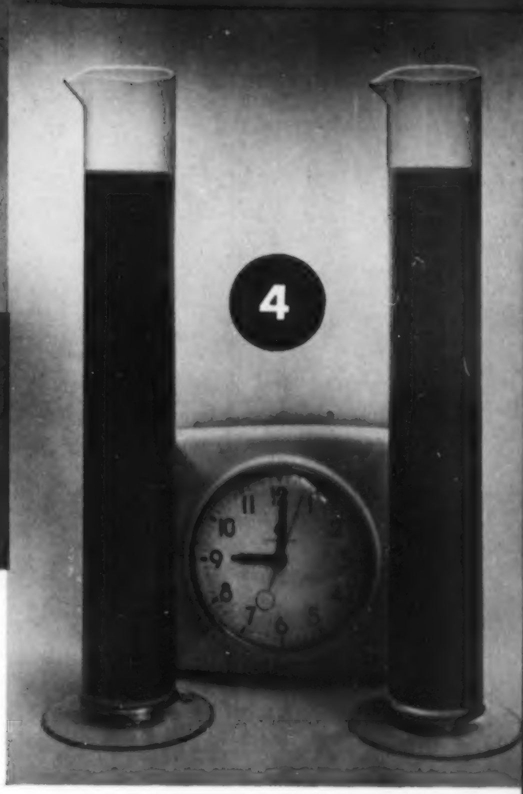
As a filter aid in operating plants, AEROFLOC Reagents increase filtration rates, make filter cakes firmer and more porous, help to prevent blinding of filter cloth and increase washing ease and efficiency.

In new and existing plants AEROFLOC Reagents can reduce capital expenditure by increasing the capacity of existing thickening and filtration installations, or reducing size of new units required.

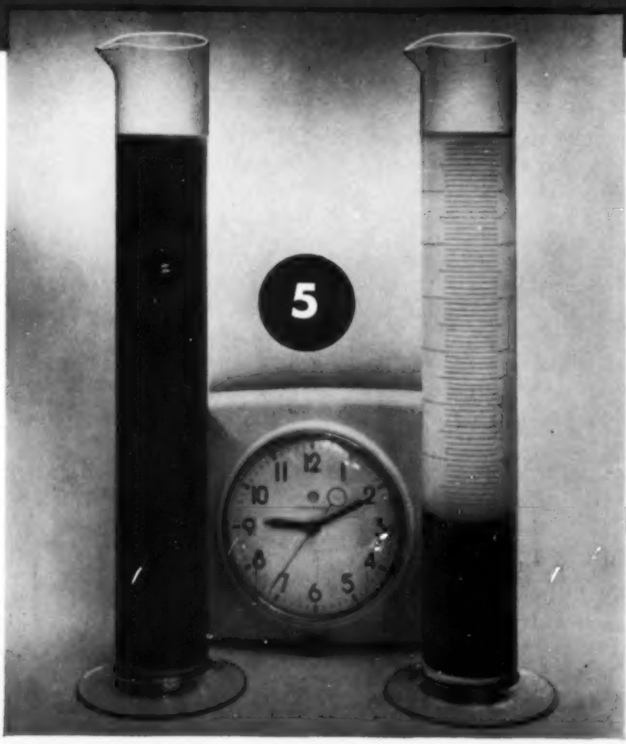
Cyanamid Field Engineers will be happy to work with you in your mill on the application of AEROFLOC Reagents to your particular settling and filtration operations.

AMERICAN Cyanamid COMPANY





to settle slimes *quickly*



Please send data on the two
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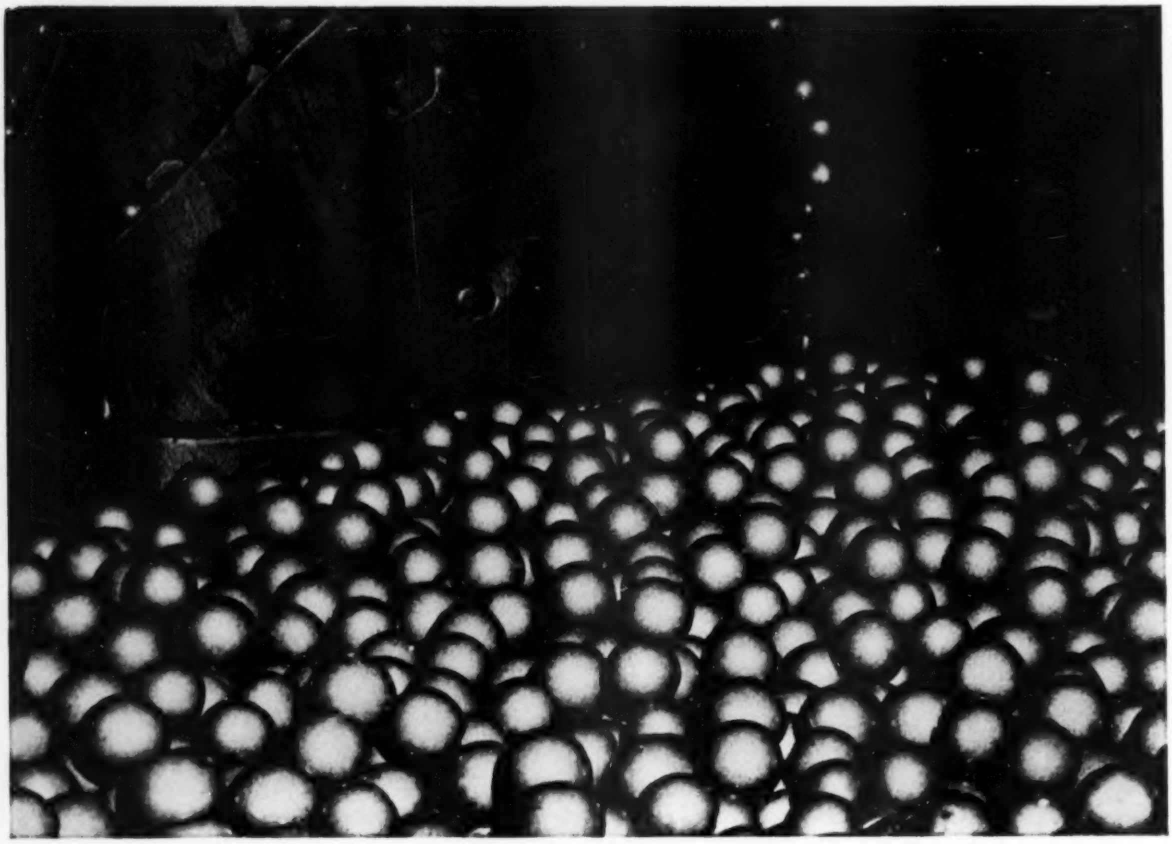

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GRINDING BALLS

Sheffield copper molybdenum alloy steel grinding balls are manufactured by automatically controlled methods which produce a ball of finer, denser, more uniform structure.

Moly-Cop balls wear evenly and retain their spherical shape longer. They have greater hardness for wear and toughness to resist spalling and chipping. This all adds up to high production rates with less down time, less charging and less power.

Moly-Cop grinding balls can make an important net saving in your grinding cost.

If you have not already proven the value of Moly-Cop balls, get in touch with us before making your next purchase.

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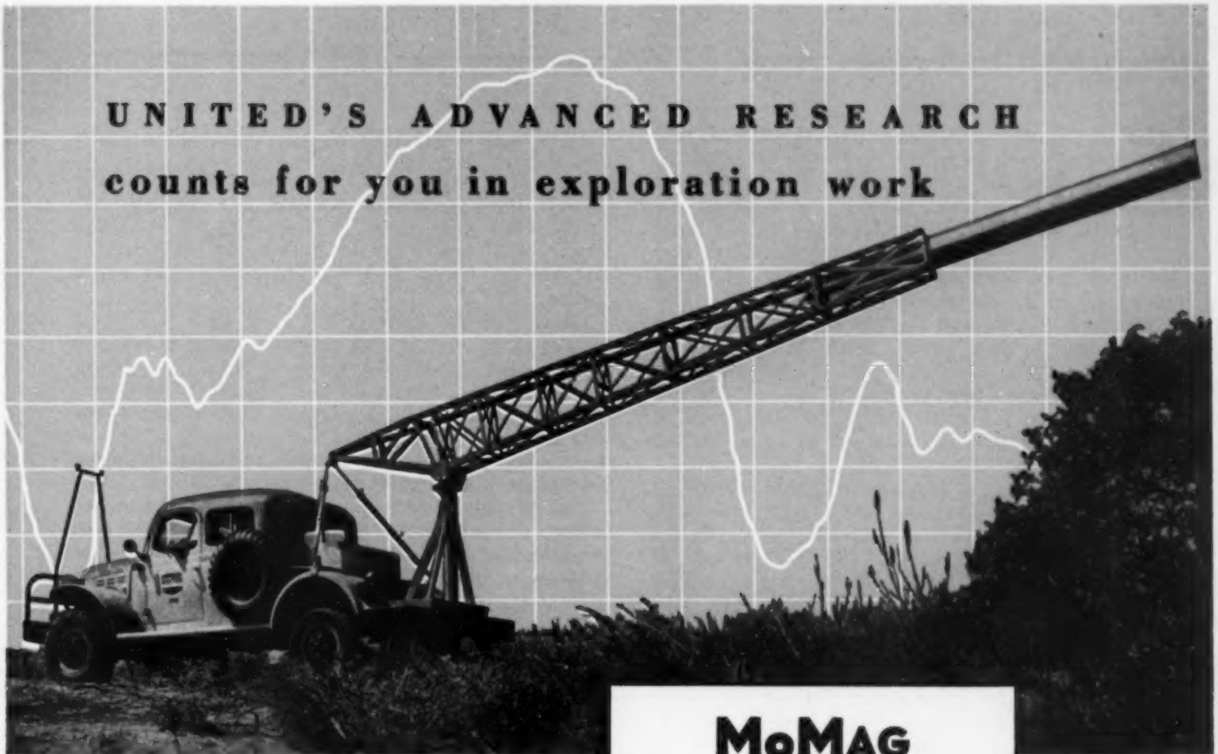

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ONE of the most fabulous annual reports to cross editorial desks in recent years has been turned out by the Arabian American Oil Co. Four-color reproduction is scattered liberally throughout the publication, leading off with pictures of the late King and present King of Saudi Arabia. Headings and type faces have been styled in a manner somewhat like a copy of the *Rubaiyat*.

The use of Arabic and English versions make it a book without a back cover. Since Arabic is read from right to left, it starts where English normally ends. The idea has been carried to the point where both covers are the same except for difference in alphabet. The reports are identical down to the last color illustration.

In recent years U. S. firms have shown increasing interest in producing reports that present the company's year-end position in a clearer light. It has lead to employment of some of the finest aspects of the typographical art. Much attention has been paid to use of illustration, good writing, and layout. Behind the move toward more lucid annual reports, at least in part, have been the Merit Awards presented by the *Financial World*, weekly business publication. Requirements for an award weren't too tough a few years ago, but the contest has been streamlined in keeping with improved quality. Management has to turn out a really fine job in order to even achieve the first qualifying citation. Among the 114 companies that made the first step this year were 30 mining outfits. Kennecott Copper, which has been in the top group for some ten years, led the minerals parade.

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A coal operator recently commented that he felt much like a battered football player whose team is losing 90 to 0 at the half-time mark. The coach gathers his stalwarts about him in the locker room and delivers a pep talk, finishing with an exhortation to "go out there and fight." The coach omits a significant item—how this derring-do is to be brought about by 11 rather tattered individuals. Right now, the coal operator continued, a lot of people are telling us that all we have to do to solve our problems is to sell more coal. "How are we supposed to do it?"

A committee of industry leaders and members of Congress think they have come up with at least part of the answer. They have made some proposals to the President that they feel will go a long way to easing the situation.

The committee wants Government to formulate and announce a policy encouraging the use of coal. They would like enough action to maintain a production of at least 450 million tons a year. Coal output reached 670 million tons in 1947, but last year dropped under the 450 million mark. Another suggestion made to the President was to limit imports of competing fuels such as residual oil and natural gas.

The committee felt that Venezuela should be aided in improving its technology to the point where more efficient refining of petroleum would result in less residual oil production. The industry-Congressional group also urged that European Governments be persuaded to lift import restrictions that discriminate against U. S. coal.

On the domestic front the coal men want protection from excessive natural gas competition. They want coal used in Government buildings where available. The committee also objected to the use of atomic piles to fuel commercial steam plants.

Other policies desired are ones that will limit freight rates on coal and promote research into the uses of coal. Where Government enters the power picture the coal men want coal considered in determining cost of points of consumption. Government was also asked to consider the possibility of establishing regular channels of communication between the industry and Government on the Cabinet level.

The President has appointed another committee to help the industry. It will be the job of this new group to dig up ways and means for bringing relief to beleaguered coal operators and it is indicated that the committee has been asked to work fast.

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MINERALS YEARBOOK 1950 states that "Indium is consumed principally in producing high-quality engine bearings and, to a smaller extent, in fusible alloys and special solders." The *Yearbook* is singularly unexcited in its description of the metal.

Indium has been called the 20th century Cinderella metal, but thus far it hasn't gone for many rides in the golden coach. It's still a poor relation languishing in the scullery. But research men are beginning to look for new uses for the metal and it may yet rise to a more glamorous position in life.

Indium was discovered in 1863 by Reich and Richter while analyzing zinc ore samples at the Freiberg School of Mines in Germany. They named their find indium because spectroscopic inspection disclosed a deep indigo-blue line. The discovery of indium hardly shocked the foundations of science. The metal was much too rare to attract attention. Tests showed that zinc ore, where indium is usually found, contained as little as a third of an ounce per ton. By 1924 world indium supply reached the grand total of a little less than an ounce.

Indium, one of the softest metals known, can almost be chewed like gum. Lead is four times as hard. A half inch bar of indium can be bent by hand with no trouble. Like tin, a close cousin, it cries or crackles under stress. Right now, the Sullivan mine at Kimberly, B. C., is probably the largest known indium source. Consolidated Mining & Smelting Co. of Canada Ltd. found traces of the metal in zinc concentrates shipped from the property to its Trail plants.

Two years after extraction tests started, about 30 lb of refined indium were produced in Cominco laboratories. Indium was traced through lead and zinc smelting processes and a recoverable accumulation was found in one of the process slags. While Cominco can produce about 1 million oz annually, production is much less because of the small demand. Another 10 million oz are available in by-product stockpiles.

Indium is being used as indicator in atomic piles. Radio activity can be induced easily in the metal. As an ingredient of solders it lowers melting point considerably. An indium-tin alloy makes an effective glass-to-glass and glass-to-metal seal. Applied to bearings in some aircraft and racing engines it has valuable antiseizure qualities. Low melting point alloys of indium have been used in surgical casts, foundry patterns, safety plugs, and dental alloys. It is also being used in some of the transistors now replacing vacuum tubes.

WILLIAM E. Wrather, director of the U. S. Geological Survey, in commenting on his department's work, says, "a lot of the things we found out 30 years ago are just now turning out to be useful to somebody. And some of the things we are learning today may not prove valuable for another 30 years."

His comment appears in an article in a recent issue of *The Saturday Evening Post*. One of the things emphasized is the running battle that has been fought by the USGS to stick to the original concept of its work—the mapping of the entire U. S. Pressure has been exerted on the Geological Survey at various times to benefit individual groups of citizens by studying specific problems affecting industry. However, the Survey works for other Government agencies, for states and municipalities, and for the public.

Whatever it learns is available to all—except for secret military data. Anyone can profit from the Survey's work with the exception of the men who are employed by it.

One direct result of what might be termed an indirect approach is that the U. S. now has enough niobium—the stuff with which jets cannot do without—in Arkansas aluminum ores and certain titanium deposits to make the nation independent of foreign sources.

STANDING on steel legs rooted in bedrock and extending 132 ft below street level, San Francisco's first skyscraper is starting to take shape under the rigid earthquake code adopted in 1948. When the code was passed there was a widespread belief that the restrictions it imposed would bring an end to skyscraper construction in San Francisco. The building, under construction for Equitable Life Assurance Society, will be San Francisco's first tall building with steel foundations resting in bedrock.

U. S. Steel Corp.'s Consolidated Western Steel div. is erecting the structural framework for the 25-story building. U. S. Steel is also supplying 5300 tons of fabricated steel, 3300 tons of steel piling. and 50 tons of stainless steel.

Design of the building involves use of uniformly tapered columns and butterfly-shaped spandrel beams in the exterior walls up through the 14th floor in place of conventional straight columns and beams. Another innovation is the use of high strength steel bolting instead of rivets. While not generally associated with building construction, the immediate advantage of bolting will be to cut construction noise. Air impact wrenches make less racket than riveting hammers. Welding will also be employed in certain areas. Stainless steel will be used extensively for the exterior finish of the building and in the main lobby. Facade will combine steel, aluminum, and white marble.

Another piece of building history was made recently on an early summer day in New York City. Starting at about 6:02 am, some 40 construction men swarmed over the bare framework of a new building at 57th Street and Park Ave. By 4 pm they had completely emplaced the aluminum outer curtain of the structure. Previous record, set by the same firm, Tishman Realty & Construction Co. Inc., was six and a half days. Aluminum panels were fabricated from Alcoa sheet by General Bronze Corp. They also furnished the crew of 40 men. Special supervisory personnel were also detailed to the job. Commented one construction man, "I never saw so many foremen on one job in my life."

Panels were distributed in strategic spots throughout the building. Actually, only one small detail was omitted from the master plan. The whistle that started work had to be borrowed from a passing policeman.

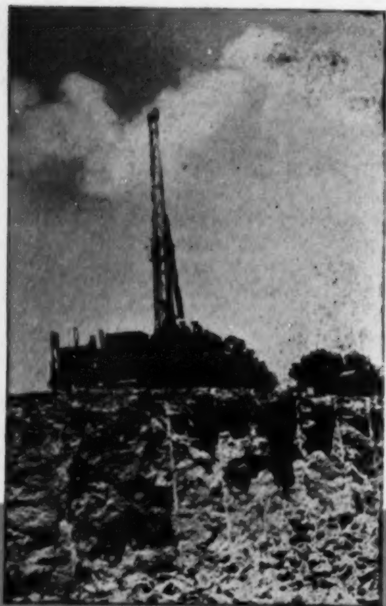
THERE seemed to be a general agreement on at least one point during the recent meeting of the American Society for Engineering Education at the University of Illinois. Somewhere along the line engineering students were not being adequately trained for the job of learning to be engineers. Among the long list of influences which come to bear during the training period, L. E. Grinter, president of ASEE, trained his sights on the public school system and the employing group that accepts the product resulting from the total education cycle.

"One of the major factors that necessarily influence the character of engineering education is the quality and quantity of secondary school preparation," Mr. Grinter said. He was of the opinion that the student's capacity to pass mathematical and scientific subject matter is indicative of the job being done by the schools, and he felt that, "a continuing loss [in that area] certainly is taking place." Mr. Grinter stated that the current attitude in public schools is one that discounts the importance of rigorous courses such as mathematics. This, despite the insistence by employers that the ability to write clearly and to make simple mathematical calculations are the most important tools high school graduates can bring to industry.

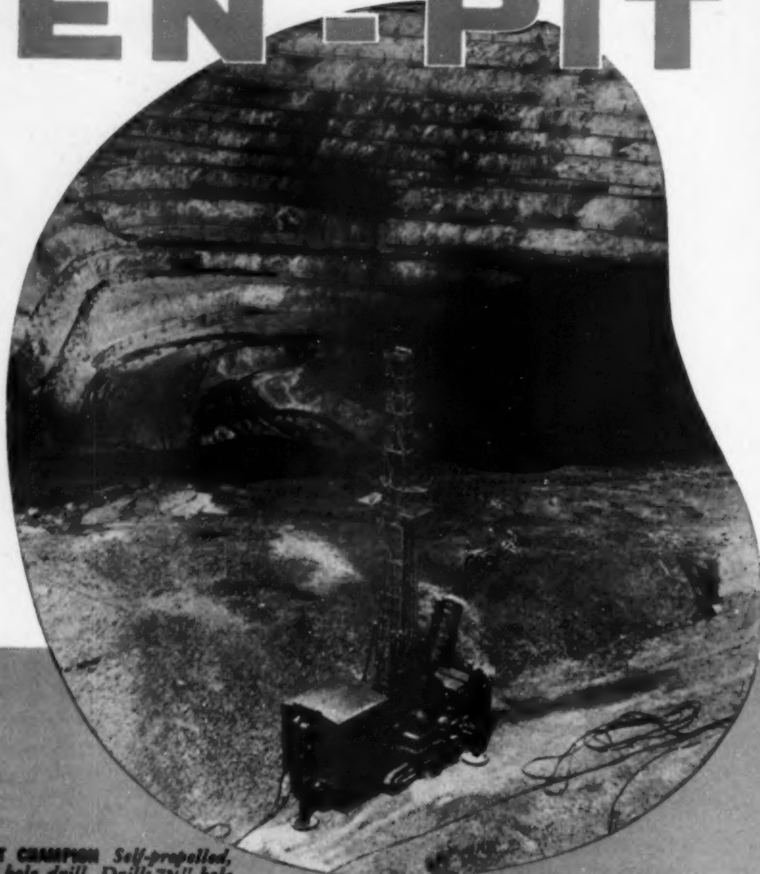
He argued against the concept that, "We can, and therefore, we must try to accomplish everything for every student." Mr. Grinter decried the system of electives that allows only a small degree of free choice. He desires a return to a system that recognizes the existence of the individual. Electives should be chosen with proper guidance, however.

He labeled the greatest weakness in engineering education as, "Neither the neglect of practice nor of specialized science but insufficient attention to welding these together so that the student can explain the rules of engineering art or practice . . ."

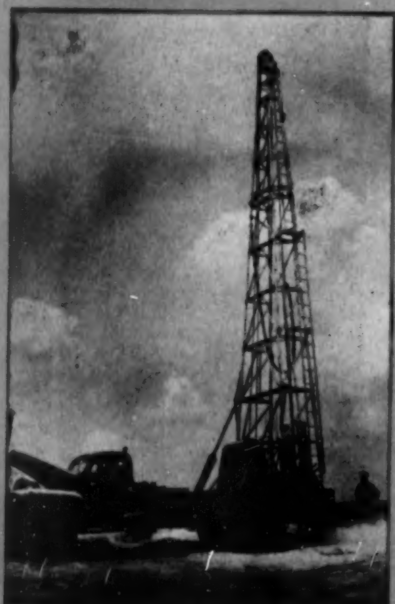
OPEN-PIT



MIDDLEWEIGHT CHAMPION *Self-propelled, rotary blast hole drill. 6¼" holes to 50'. For all formations where rotary drilling is practical.*

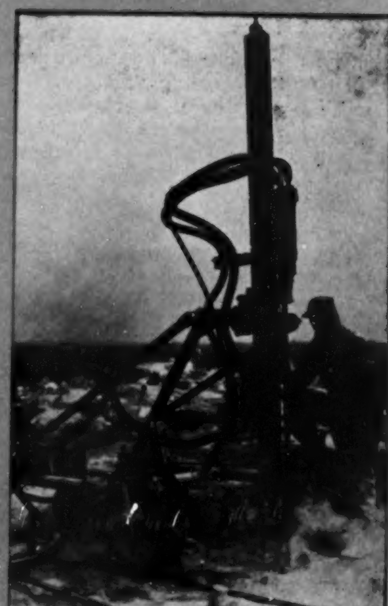


HEAVYWEIGHT CHAMPION *Self-propelled, rotary blast hole drill. Drills 7⅞" hole to 200' in any formation where rotary cone-type bits are applicable.*



MODEL 22S *Truck-mounted rotary which produces holes to 6¾", 150' deep. Similar but smaller model is #75 which drills a 4⅝" hole 50' deep.*

CHALLENGER *A self-propelled hammer drill that produces a 4½" hole to 50'. Very maneuverable.*



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50′	4¾″	Truck-mounted rotaries for fast moving between holes. For blast hole drilling with drag or rotary cone-type bits in all except hard formations.	No. 75 Drill Rig
150′	6¼″		No. 225 Drill Rig
50′	6¼″	Self-propelled rotary blast hole drills for all formations where rotary cone-type bits are applicable.	Middleweight Champion
200′	7⅞″		Heavyweight Champion

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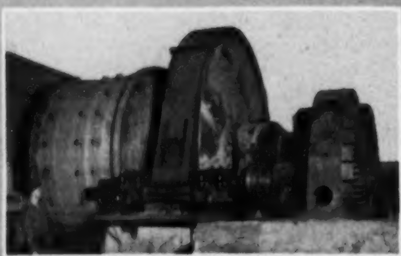
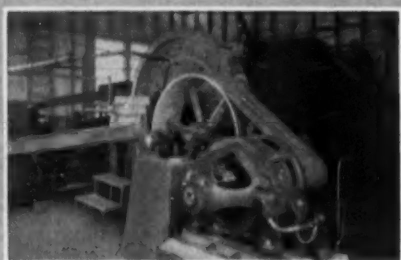


Direct connected drive with flexible coupling



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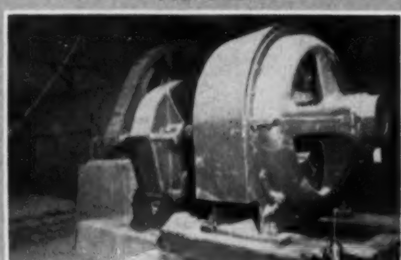

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Drift of Things

OVER $4.2 billion worth of raw material was poured into the U. S. economy by the mining group in 1953—yet search as you wish and it is impossible to say, "Here is technically up-to-date literature describing and explaining this vast industry".

Importance of mining to the economic community is unquestioned, but do you realize that virtually no up-to-date textbook or manual has been published in this field for at least 15 years, and even those printed at that time were outdated by another ten years when they were printed? This astonishing fact does not hold true for all groups of the Mining Branch, however, it is a good general statement. Geology and Geophysics are considerably more active along this line, but in other fields of endeavor within the group, nothing but elementary college publications have appeared, and only a few of these.

We are dragging our feet!

As an example, the matter of revising the *Mining Engineers' Handbook* was brought to the attention of a group in AIME several months past. The publishers of this volume have found that the book in its present style cannot be revised because of the exorbitant cost involved and the relatively small market. But an alternate proposal was made by the publishers, who suggested a revision and format change for the large section of the handbook covering mining methods. They proposed a book utilizing graphic presentation on a larger page, similar to the new data books. They also asked that this interested group act as a permanent committee to aid the publishers in preparing the material and guiding the editorial content. The reply to this proposal was most enthusiastic and all were positive that a revision should be made. But by someone else!

A revision of the 1933 Lindgren geology volume is in the air. But now some areas of the membership are not even sure that a revision of the 21-year old book is even needed! It would be a startling revelation if the science and techniques of this profession had progressed so little in two decades that a new case book would not be warranted.

These are but two instances, to cite more would make it appear that we are condemning individuals, which we are not. This tirade is a sincere expression of the feeling that we are taking a back seat, that failure to make available technology in the minerals engineering field will retard the industry. The least such a lack can do is retard the engineers themselves—for they will find themselves giving way to specialists from other fields, fields which constantly increase the scope and detail of their technical literature.

MINING ENGINEERING and AIME *Transactions* have been the only advanced material appearing in print, but this form is not always the most convenient for passing on valuable information.

It would almost seem that we exist technically in spite of ourselves. It is appalling to find that many mining engineering textbooks now in use look like *De Re Metallica* with an electric motor instead of a treadmill.

And what of the handicap this poses for the professors of mining engineering? Certainly they try to teach the most modern methods without the material to ease and speed the process. And what about the student himself? In college he will find that many of the basic textbooks have copyright dates that resemble those of a collector's library. The year 1920 is almost a modern publication.

Leaving aside difficulties of studying from notes and periodicals, the college student's principal contact with mining is through the printed page. Do outdated texts create much of an impression?

How did this situation come about?

To a large degree this lack of adequate technical literature stems from the fact that mining is not an industry born under competition, but one that came into being through necessity. It is easy to see that virtually any group that did not have to force itself upon our economic system tends to be conservative. This is understandable to a point, but only to a point.

And what can we do about it?

One group is doing something about the problem of information. The Mineral Economics Div. has gained both Divisional and Institute approval of a broad project to produce a volume to fill an existing gap. Going ahead under the outline of "A Code of Economic Principles Pertaining to Exploration, Development, and Exploitation of Mineral Deposits," this group aims to cover vital factors affecting mineral enterprises *other* than those that lend themselves to solution through science or technology. But what about our job, the factors that do lend themselves to solution through science and technology?

We have a team of technically competent men in the Mining Branch. In the AIME we also have the mechanism for publishing the material—but we must have the spark that comes only from individuals. Perhaps if the remarks made here are just strong enough, some of the individuals with this spark will get angry, come forward, and start to put an accurate picture of modern mining in print now. Not as history!

FOLLOWING a similar line of thought, but without any idea of seriousness, a small book we saw recently made us immediately think of mining textbooks. Published in 1834 as one of a series in Peter Parley's Little Library, title of the volume is *The Mine; or Sketches of the Mines of Different Countries, The Modes of Working Them, and Their Various Productions*. Other notable books in this series included *The Adventures of Capt. James Riley in Africa* and *Story of Alexander Selkirk, Who Inhabited a Solitary Island Alone, for Several Years*. Could it be that we are just taking a negative attitude about the whole thing?

Charles M. Cooley

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The Caterpillar No. 80 Scraper in the picture removed nearly all the clay overburden from this 100-foot-deep pit. It was then used to move iron ore to the washing plant of Hodge Mining Company at this operation 7 miles north of Canton, Ga. Cycle time was 8½ to 9 minutes over a haul distance of 2000 feet, involving extremely stiff grades out of the pit.

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Proposed Mineral Economics Volume —

"A Code of Economic Principles Pertaining to Exploration, Development, and Exploitation of Mineral Deposits"

by Charles W. Merrill

WHETHER the valuable components in a mineral deposit can be mined and separated from the worthless matrix, processed, and marketed depends not only upon the natural factors and the physical and chemical techniques, but also upon many extrinsic factors relevant to the economics of the business of exploring, developing, and producing minerals.

To meet a need for proper coverage of this specialized field of economics, the Mineral Economics Div. of the AIME has developed a plan for assembling a volume setting forth important factors affecting mineral enterprises other than those that lend themselves to solution through science or technology. The program has been considered by the Institute's Directors and they have approved it, subject to a decision of the Mineral Economics Div. to carry it out.*

What is written here will be descriptive of the program, and suggestive as to the subjects that might be covered and the approach to them. The author is emphasizing the word suggestive. Some of the subjects proposed may be judged trivial or irrelevant. Other important subjects may have been overlooked. Amendments to these introductory remarks will be eagerly welcomed.

This is to be a symposium compiled by experts covering all the important phases of manmade laws, regulations, and extrinsic factors that affect the economy of these businesses. Those who prepare the volume hope that it can be utilized by consultants, operators, entrepreneurs, financiers, legislators, administrators, and jurists of the Federal and State Governments, and serve in the libraries of the mining colleges and as a text or reference for instruction in their classrooms. Under each subdivision the authors will include a selected bibliography.

It should be clear that a utilization of mineral resources can be affected as much by political and other manmade rules as it is dependent upon understanding of natural laws or the application of an advanced technology. Only too frequently are the imagination, knowledge, and ingenuity of engineers thwarted in the development of mineral resources by such elements as inequitable taxation, restrictive international trade regulation, or other conditions of a political nature.

It is clear that AIME should continue to apply its principal energies to the advancement of mineral technology, but such devotion to engineering and science should not become a preoccupation, blinding the Institute to the political and social factors that can negate the practical usefulness of the finest technical accomplishments.

Before outlining the subjects a few general observations seem appropriate. First, the analyses assume a modern society with at least a partly industrialized economy, under a democratic, free enterprise system. A totalitarian government would make most of the discussion irrelevant. Also, in an agrarian or pastoral society, mineral utilization has little significance. Common factors will be found in more than one of the subjects. For example, international competition is a major consideration in setting tariff rates, but is also a limiting factor in internal taxation and subsidies. Other examples of interdependence of subjects include use of tax remission as a form of subsidy, or of subsidies as a form of emergency controls.

To elaborate the 14 nontechnical elements listed below, each will be treated in a separate paper. The following paragraphs suggest in outline form some major significance of these subjects, and the political climate in which technology and craftsmanship may make natural mineral resources useful to man.

CHARLES W. MERRILL is Assistant Chief, Minerals Div., U. S. Bureau of Mines, Washington, D. C.

*Status of the Project

The remarks condensed here were originally given at a session of the Mineral Economics Div. during the February 1954 Annual Meeting. At that time, the project, suggested by the Chairman of the Division in consultation with the Division Executive Committee, had received approval from the AIME Directors. Under the chairmanship of James K. Richardson the MED is going ahead with the whole project. The committee to study the handbook project, Evan Just, Charles Behre, Jr., and E. W. Pehrson, has prepared a report outlining chapter topics so that parts will be integrated even though separate parts are written by different authors.

It has been suggested that the remarks by Mr. Merrill might, with appropriate rewording, serve as an introduction to the proposed volume. At the same session two papers were presented which might form the basis of chapters of the volume, these were: "Mineral Taxation," by G. S. Borden, and "Major Changes in Mineral Demands," by W. C. Schroeder.

Fourteen Proposed Topics for the Mineral Economics Handbook

LAND TENANCY AND USE—Perhaps the most fundamental of all political decisions affecting the development of natural mineral resources revolves about land tenancy. At one extreme is the Communist concept that all resources and means of production are vested in the State. At the other is the concept of private fee own-

ership extending to the center of the earth. Lying between are varying degrees of the regalian principle. Here subsurface title rests in the Crown or State but the stimulating benefits of private enterprise may be utilized under leases, or concessions, or on shares. In addition to the terms of tenancy, there are regulations on land use as applied through zoning laws, surface restoration requirements, and the like, which present problems to those in mining.

TAXATION—Taxation rivals land tenancy in its effect on the development and exploitation of natural mineral resources. The enormous wealth-producing potential of mineral-resources exploitation makes it an important source of tax revenue. There can be no just reason why the mineral industries should not carry a substantial part of the tax burden where mineral resources are abundant and in production. However, certain problems in mineral-industry taxation call for unusual caution. An idle mineral deposit will not yield a large tax revenue for long. Consequently, tax schedules should permit the profits that encourage the enormous capital outlays that must precede mineral exploitation.

Tax legislation is in an endless state of flux. The regulations of the assessors and collectors are equally changeable. Moreover, both laws and regulations are continually being tested in court. As a result, any presentation of the mineral taxation must be revised frequently to be useful.

SUBSIDIES—Whereas taxation tends to restrict mineral resource development and exploitation, various forms of aid provided from tax funds are normally designed to increase mineral output. Such aid can take the indirect form of providing technical and economic advice through Government bureaus, or it can be more direct in permitting remission of taxes or providing grants to particular operators engaged in such activities as exploration and metallurgical research. Even premium payments for production have been provided as an important form of stimulation in emergencies.

INTERNATIONAL TARIFFS AND TRADE—Because of the erratic distribution of minerals, most of them must be transported considerable distances from point of production to market. Such movements frequently are international. Virtually the entire United States supply of certain minerals comes from abroad. Thus, tariffs, embargoes, quotas, international exchange restrictions, shipping monopolies, and other restraints on international trade are all of major importance in mineral utilization.

FINANCE—The enormous aggregation of capital required for financing most mineral enterprises and the high risks involved in many mineral-production businesses make the problem of financing a serious one. General regulations designed to protect unwary investors from fraudulant financing easily can be so stringent as to make the promotion of mineral enterprises almost impossible. On the other hand, an unregulated market for securities based on mineral enterprise could result in this field of finance being crowded through an influx of dishonest and unscrupulous promoters.

MONETARY STABILITY AND GOLD—Among the most difficult factors to forecast in developing a prospectus in mine finance is the price level of the product compared with the level at which labor, equipment, and supplies will be available. The prospect of inflation or deflation, as may result from unpredictable monetary policy, is adverse to the type of long-term financing needed in almost all new mineral enterprises promising major production.

The mining industry has a double interest in sound monetary policy: 1) as a market for its money metals —gold and to a smaller extent silver, and 2) an interest shared by all industry in sound money.

EMERGENCY CONTROLS—The record of the last half century has been one of wars and recurring emergencies, which have resulted in the imposition of innumerable Government controls, mostly temporary, on private activities in the United States and elsewhere. Because of the essentiality of minerals in industrial operations, defense, and in war, the industry has come under Government regulation to as great an extent as any major segment of human activity.

ANTITRUST AND SIMILAR LEGISLATION—Mineral occurrence and recovery methods sometimes provide unusual opportunities for private business monopoly. Such ore deposits as those at Sudbury, Ont., and Climax, Colo., contain concentrations of superior ore that give their owners a dominant commercial position in the world. Patented metallurgical processes can foster concentrated industrial strength. The mineral industry must be prepared to meet public demand for antitrust and other similar restrictive legislation to avoid punitive measures and promote the public welfare through private expansion.

MAJOR CHANGES IN MINERAL DEMAND—The mineral industry is subject to major, sudden, and unpredictable changes in the demands placed upon it. A new use may develop with little warning, as when the fission of the atom created a demand for uranium that transformed the economy of a large area centering in southwestern Colorado. The progressive and rapid displacement of hot-dip tin plate by electrolytic tin plate has caused a depression in tin demand, with a major impact on Bolivia and southeast Asia. Cyclical economic changes have a profound effect, as when a business depression forces the closing of mines that are the sole source of livelihood in an isolated community.

LABOR POLICY—The unusual working conditions under which minerals are produced make labor policy a serious problem. Among major fields of employment, work in mines, particularly of the underground type, is far more hazardous than most other forms of employment. Special accident and health problems must be met. Limitations of the working hours and inclusion of travel time to and from working places frequently reduce the effective part of the shift and greatly increase labor costs. Labor legislation fostering union activities can have a critical effect on the industry.

VALUATION—Valuation in itself might not be a special mineral problem, except that the appraisal of mineral deposits and enterprises raises many difficult and some unique questions. Valuation, however, frequently is a central factor in taxation, finance, tariff rates, monetary decisions, and other problems facing the mineral industry. Equity demands firm and recognized standards of valuation.

ACCOUNTING—Accountancy also finds itself faced with extraordinary problems when applied to the mineral industries. Here, too, recognized standards are of the greatest importance to those involved in mineral enterprises.

TRANSPORTATION—Transportation and minerals are very closely related. The search for minerals has been a major factor in the exploration of the remote and undeveloped parts of the world, and exploitation of mineral discoveries usually calls for the development of transportation facilities.

INSURANCE—The provision of insurance in connection with mineral enterprises presents special difficulties. Protection against risks to property is usually very expensive in the case of mines because of locations remote from community facilities like fire and police departments. Protection for the working forces against the hazards to health, accident, and disaster usually is far more costly than similar protection in other lines of work.

Chrome Mining in Southern Rhodesia Shows Wide Variety of Operations

Three types of orebody: thin seam, sackform, and disseminated— Mining ranges from "Pig-Rooting" to large scale modern ventures

by Parke A. Hodges

CHROMIUM, one of the most vital of the strategic metals, has constantly increasing importance as research expands potential uses in alloy steel metallurgy. All signs point to a steadily growing use for chrome ore, and the general subject has received a great deal of attention recently.[1]

A relatively little known country, Southern Rhodesia produced a total of 5.949 million tons, or 18.6 pct of the total world chrome output, between 1906 and 1950, according to figures from the U. S. Dept. of Commerce. According to U. S. Bureau of Mines figures, Southern Rhodesia produced 291,525 tons in 1950 and 300,267 tons in 1951, or approximately 13 and 11 pct, respectively, of world production for the two years. In 1953 the Rhodesian Vanadium Corp. produced about 85,000 tons of which probably 7,000 tons were concentrate. Production by other companies was high. Large in themselves, the figures assume even greater significance because most of this output is of metallurgical grade.

Southern Rhodesian chrome mining includes the great sackform type deposit at Selukwe, operated by African Chrome Mines Ltd., one of the first companies established, and numerous relatively small operations scattered along the Great Dike. These latter operations vary from well-organized and equipped mines, producing up to 2000 tons or more of chrome per month, to *pig-rooting* operations carried out by a single settler with the aid of 30 to 50 *boys*. It is understood that at present the Great Dike production accounts for roughly 40 pct of total output, the balance coming from Selukwe.

Geographic Setting: A High Region Surrounded by Lower Country

Southern Rhodesia is located in southern central Africa, lying roughly between 16° and 23° south latitude, and 25° to 33° east longitude. Neither it nor its neighboring colony, Northern Rhodesia, has a seaport, and all exports have to be shipped either through the port of Beira, in Portuguese East Africa, or through one of the ports in the Union of South Africa, usually Durban or Port Elizabeth.

The central portion of Southern Rhodesia forms a plateau dominated by a peneplain. At the northeastern end of the colony the plateau joins a narrow belt of mountainous country, and in this area the altitude rises above 6000 ft. Toward the southeast and west the elevation is lower, being below 2000 ft. However, over 21 pct of the area of the colony is above the 4000-ft level. On the high plateaus the climate is relatively healthy, although in the lower locations the usual tropical discomforts of heat and disease are experienced.

PARKE A. HODGES is a Consulting Engineer, New York City and Vice President, Behre Dolbear & Co.

Mining in Southern Rhodesia can take the most primitive and simple forms. Hand labor, crude methods, and backbreaking work are all part of this prospecting team's lot at Belingwe, at the extreme southern tip of the Great Dike.

In recent years there has been a great influx of immigrants from England and other countries. At present the white population is in the neighborhood of 140,000. The native population is probably in excess of 2 million. Although towns are small, living conditions for the Europeans, on the whole, are excellent. Education is available for children, and sanitary and other conditions are taken care of by the Colonial Government.

Chrome mining started early in the 1900's, and originally was confined to the great sackform deposit at Selukwe. Several chrome mining concerns were organized, largely under the management of a group including the late Sir Edmund Davis, to exploit the Selukwe and other deposits throughout Southern Rhodesia. This group of related companies has consistently produced the major part of Southern Rhodesian chromite.

Chrome Mining Began about 50 Years Ago at Selukwe

In the early 1930's the Vanadium Corp. of America took over a large block of claims in the Umvukwe District, and organized the Rhodesian Vanadium Corp. Operations were spasmodic, practically ceasing during the great depression of 1930, and did not become of major importance until about 1939. Then, with the increased demand for chromite brought on by World War II, various companies and individuals began to operate along the Dike. Some of these banded together into syndicates, such as Chrome Producers Ltd., and in the aggregate their output was considerable. The established companies greatly increased production, and Rhodesian Vanadium Corp. resumed operation about 1945. Since that time chromite output has steadily increased.

Most of the Southern Rhodesian chromites are of metallurgical grade containing 48 pct or more

Cr_2O_3 and have a chrome to iron ratio of 2.8 to 1, or better. In certain localities, ores of refractory grade are found and the reserves of both types are considerable. At present submetallurgical ores and concentrates are also produced. Practically no ore of chemical grade is mined as the expense of mining and shipping makes the production of these ores unprofitable.

Chromite occurs in seams, from 1 to 30 in. thick, extending continuously for many miles along the Great Dike, as well as in the great sackform deposit near Selukwe, and in smaller pod-like masses in the same area. Deposits also occur near Mashaba, but are of lesser importance. In addition, there is a considerable amount of disseminated ore that is successfully mined at the Spotts Mine, and other places along the Great Dike. These disseminated ores have to be concentrated by milling to produce a chromite concentrate.

About 1948, attention was given to alluvial ores which are found along the margins of the Great Dike for 250 miles from Lalapanzi to the Umvukwe hills. These alluvial ores consist of grains of chromite, which have been concentrated in the surface soil by weathering and the action of surface water, and can be mined and washed in much the same way that beach sands are treated in other parts of the world. Treatment is relatively simple and yields a high grade concentrate with an excellent chrome-iron ratio. It is a sand-like product, however, for which the market is somewhat limited at present.

Two Main Sources: Sackform Deposit at Selukwe and the Thin Seams of the Great Dike

The great sackform deposit at Selukwe, which consists of the usual magmatic segregation of chromite, has been described by Lightfoot, Maufe, and others.[3] Noteworthy for its great size, being one of the largest single concentrations of high grade chromite in the world, it has been intensively explored both by underground drifting and diamond drilling. No information is furnished by African Chrome Mines Ltd. relative to the size or grade of its developed reserve but it is obvious from the type of mining and treatment plants already constructed and proposed that these reserves must be very substantial.

Smaller lenticular deposits are also found near Selukwe and Mashaba but these are at present of lesser importance.

The genesis of the thin seam deposits which occur along the Great Dike has not been definitely determined. B. Lightfoot[3] and others have written extensively on this subject and there is considerable difference in their interpretation of the possible occurrence of these ores. The earlier writings of Lightfoot, Maufe, and Keep indicated that the Dike was a relatively shallow laccolith and that the chromite seams occur therein due to magmatic segregation, or possibly a series of segregations of the Dike magma. This concept has been described in considerable detail by F. E. Keep.[4]

Otto Weiss,[5] in 1940, carried out a geophysical exploration in certain areas of the Dike and is of the opinion that, in the areas where he carried out his work, the Dike has nearly vertical walls and extends to great depths. For further discussion of the possible genesis of these ores, the reader is referred to the bibliography.

There are seven known seams that occur in the dike-like mass of highly serpentinized ultrabasic rocks, many of which are enstatite-bearing, that form the "Great Dike of Southern Rhodesia." This Dike, 3 to 6 miles wide, can be traced continuously for 340 miles and is an outstanding geological feature of the colony. The mass is a composite body with a remarkable layered structure. Small bodies of granitic rock are found within the Dike at several places. They occur usually as small veins or dikes with very steep dips. The Dike is bounded on both sides by granites which, adjacent to the formation, have been hardened and partly crystallized and weathered as a line of rocky hills. Between these hills the Dike may form a flat and slightly sunken area. The norite and pyroxenite which frequently compose the top part of the Dike generally form hills, which, in many cases, overlook the country.

Southern Rhodesian chromite occurs in seams 1 to 30 in. thick. They extend for many miles along the Dike. The seam here has two bands of chromite, each about 4 in. thick, separated by about 15 in. of magnesite and serpentine.

Seams of chromite vary in thickness from a fraction of an inch to as much as 30 in., although 7 in. is normal and seams 3 to 5 in. thick are often mined. These seams are separated one from the other by 125 to 1700 ft of serpentinized peridotite. In some areas along the Dike it is possible to mine three or more seams, but in other areas, only one can be worked.

After formation, the seams were displaced by normal faulting. Usually this displacement amounts to only a few inches or feet but occasionally the offset is of the order of 150 to 300 ft. Frequently these faults are of the scissors or hinge variety, growing smaller or dying out as the center of the synclinal axis of the Dike is approached.

The displacement caused by this post-mineral faulting adds considerably to the difficulties of mining. When working narrow seams of this nature, the size of the extractive openings and the amount of dead work carried out must be kept to a minimum. An offset of only a few feet may entail a great deal of unproductive, but necessary work, in order to provide means of getting the ore to the surface. In the more progressive mining operations, these difficulties are being overcome in part by the increased use of scrapers and temporary chutes.

In the Umvukwe region of the Dike, the chromite seams outcrop along both sides of rolling hills occurring near the center of the Dike. In this section the seams have a synclinal structure and have been mined from one side of the hills to the other, a horizontal distance of about a half mile. The dip of the seams in this area varies from 15° to as much as 30°, depending on the distance from the center of the

Panorama shows the Prior-Orion mine, mine plant, and native compounds. Faulting is visible as well as the extraction adits.

Dike. As a rule the dip of the seams is less as the center of the Dike is approached. In other parts of the formation, the seams frequently have steeper dips, up to 50°, and it is not known whether they likewise have synclinal structure or not.

In addition to seams of nearly pure chromite, there are areas along the Dike where there is a considerable dissemination of chromite through a distance of several feet on the hanging wall side of the seams. In places such as Spotts, Lydiate, and elsewhere, it is possible to mine this disseminated zone and produce a chromite concentrate. A possible explanation of this dissemination is given by F. E. Keep.[4]

The "Mining Block" Makes Possible Control of Large Areas

It is possible to hold a *mining block*, with a maximum size of 600x4500 ft, indefinitely through payment of a nominal sum in lieu of assessment work. The amount of fee required to hold a block depends upon a complicated schedule of credits based on improvements and the amount of ore shipped. The mining block as applied to base metal claims is a group of not more than 30 claims, each having an area of 90,000 sq ft, making a total area for the block of 2.70 million sq ft, or about 0.10 sq mile. Since it is possible to hold a block as conveniently as it is to hold a small unit such as one claim, almost all locations in the colony are based on the mining block.

Base metal rights in the colony are based on vertical side lines. Since few seams are sufficiently rich to justify sinking a shaft through more than 100 ft of barren material before starting mine operations, it is usually possible to protect a seam for long horizontal distances with a few blocks. In the case of flat dipping seams, it may be necessary to locate two blocks side by side in order to allow the seam to reach an uneconomic depth below surface before it passes outside of the vertical side lines of the blocks.

Most of the known outcrops along the Dike have been located. However, payment of taxes may become onerous and a certain number of blocks become free for location each year. Many of these blocks, however, are in areas where it is known that the chrome is low grade or has a poor chrome-iron ratio, so they are not restaked. In parts of the Dike, blocks which may be profitably operated still become open for restaking.

The above remarks apply primarily to ground containing chromite seams in place. Acquisition of alluvial chromite is another matter. Since 1948, there has been considerable interest in alluvial deposits and particularly in the Birkdale-Vanad area in Umvukwe District, all possible alluvial claims are reported to have been located. However, there may be other areas open that contain worthwhile deposits of this type.

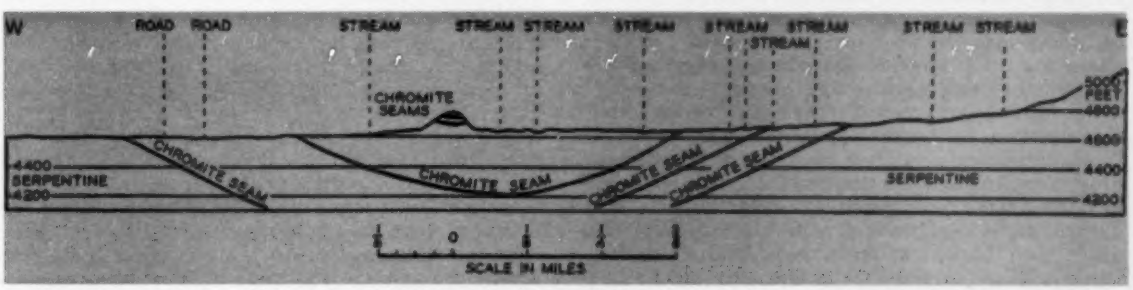
Variety of Mining Methods Find Use

Chrome mining can be divided into five categories: 1) pig-rooting; 2) the mining of the large sackform deposit at Selukwe; 3) the underground extraction of chrome from narrow seams along the Dike; 4) mining and milling of disseminated ores; and, 5) treatment of alluvial ores.

Pig-rooting: The simplest operation consists of mining the outcrop along the surface and, by the use of hand tools, removing the chrome to a maximum vertical depth of possibly 7 ft, the depth being governed by the amount of overburden that can be handled economically by hand methods. Mining of this type can be carried out with little capital investment. It is merely necessary to have enough boys and to oversee the work to make sure that the chromite is mined clean and is good quality.

The Great Sackform Deposit at Selukwe: The great sackform deposit at Selukwe is operated by large scale, low cost mining methods. No data are furnished concerning the ore reserves of this deposit, but it is probable that they are of the order of several million tons. Extensive and systematic exploration work has been carried out, and the orebody has been developed both underground and by diamond drilling.

It is understood that several mining methods are



Section across the Great Dike, at Umvukwe Range in the Lomagundi District, shows the projected synclinal structure. After *Keep*, see bibliography.

used at Selukwe, including top slicing with an 8-ft cut, shrinkage, cut-and-fill, and modified square-set methods. Production at this mine can be calculated in tons per boy per day, in contrast to the output of from 125 to 500 lb per boy per day, considered normal in the underground thin seam operations in Southern Rhodesia. It seems clear that Selukwe produces chromite at the lowest cost per ton of any operation in the colony. Since it is immediately at the railhead, cost for transporting the chromite from the mine to the railway car is low, and it is also in the principal freight zone and obtains the minimum freight rate to Beira. Thus Selukwe chromite should be delivered at Beira at a lower cost than that of any other producer.

Thin Seam Operations: From the viewpoint of the mining engineer, possibly the most interesting operations in Southern Rhodesia are those mining 3 to 7-in. thick seams of chromite by underground methods. Operation of deposits of this type pose many problems in development and mining.

Methods necessarily vary from mine to mine. Details as to the spacing of shafts, levels, and ore passes vary greatly at each individual property and change frequently due to variations in the thickness of the seam and unexpected faults. These local changes often cannot be determined in advance of actual mining operations.

In the early days the ore was mined by conventional pig-rooting methods for approximately 12 ft down dip, or 7 ft vertically. The next mining plan was to run a series of horizontal adits into the hillsides where the seams outcropped. These adits, spaced 20 to 50 ft apart along the strike of the seam, were driven at an angle across the dip of the seam, so that one or two men could handle a mine car of 10 cu ft on the resultant grade. For the sake of clean mining, the adits were originally driven with the chrome seam in the bottom and the only way to correct for an offset of the seam, up or down, caused by faulting, was to turn the adit to the right or left in order to bring the seam back into position at the floor of the adit. This method created extremely tortuous adits through which tramming could only be done with difficulty. At intervals of approximately 50 ft, connections were driven from one adit to another. These formed the start of a longwall stope, and the ore was mined out between these connections, being delivered to the mine car by means of wheelbarrows.

At some mines the chrome seam was carried half way up the side of the adit so it would not be necessary to change direction so sharply in order to correct for minor displacements in the seam due to faulting. This resulted in straighter adits and better tramming conditions due to improved grade. In addition, since the floor of the stope was 2 to 3 ft above the track level, it was possible to empty the ore directly from the wheelbarrow into the car.

As mining progressed, operators realized that some sort of mechanical haulage was needed and that mechanical drilling was desirable. Certain properties in the Umvukwe District use Little Trammer battery locomotives, electric drills, and electric cap lamps underground. Other properties depend on hand tramming and drilling, carbide lamps, and use machine drills sparingly, if at all.

A description of the methods in use at one mine is indicative of present practice, although it varies greatly. The sketches show the layout. Substantial inclined shafts, equipped for skip hoisting, are sunk parallel to, but approximately 40 ft vertically below, the chromite seam. These shafts are frequently designed to handle all the chromite produced within a distance of 500 to 1000 ft along the strike of the seam on each side. From stations spaced about 240 ft apart along the incline, flat tramming crosscuts are driven to intersect the seam. At intervals of 40 ft, vertical raises are put up to the seam. These raises serve as ore and waste passes from the four or five sublevels established between the main tramming levels. The sublevels are 40 to 50 ft apart along the dip of the seams.

Chromite seams outcrop along both sides of the rolling hills in the Umvukwe region near the center of the Great Dike. Seams have been mined from one side of the hill to the other, for a distance of about half a mile.

From the end of the flat crosscut the main tramming level is run in ore along the strike of the seam on a favorable grade. The tops of the vertical raises from the tramming crosscut are connected one to the other in ore by winzing down from the level above, and raising from one to the other. Thus a connection is made in ore from one main level to the next.

Meanwhile the shaft is sunk farther and at a point directly under the intersection of the tramming crosscut and the seam, skip loading facilities are built and two vertical raises are put up to intersect the seam. These raises act as ore and waste passes respectively. At the same time the sublevels are being carried ahead, so stoping can start on all the sublevels simultaneously when the necessary development is completed.

At intervals of about 500 ft along the strike other tramming crosscuts are driven and vertical ore passes put up to intersect the sublevels. In this way the maximum tramming in the sublevels is kept to 250 ft, and the distance of movement of material in the stopes to the cars operating in the sublevels should not exceed 20 to 25 ft.

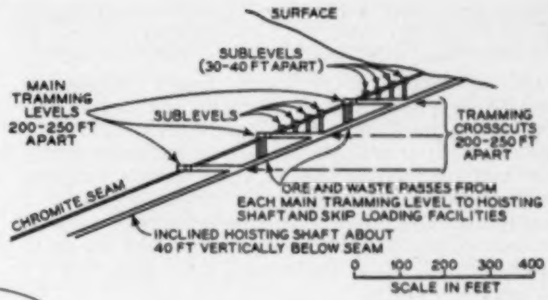
Ore and waste are moved from the stope face to the car by means of wheelbarrows or, to a lesser extent, by scrapers.

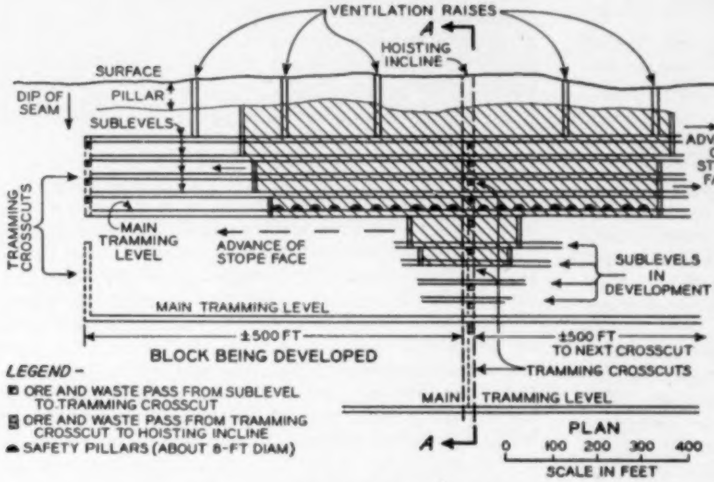
There are numerous adaptations of the above methods. Main tramming drifts and the subtramming drifts are sometimes slightly below the ore seam, connected to it by short raises. These raises serve as ore pockets. Ore in the resue stopes is moved to them by wheelbarrows and scrapers. The ore or waste from these small pockets is loaded by gravity into 1-ton cars, trammed to the main orepass at the hoisting shaft and loaded into skips for hoisting to the surface.

Other adaptions are to drive short haulage spurs from the main haulage drifts into the ore and mine up the dip of these spurs. It is sometimes possible to mine practically to the next level, due to the flat

Typical Thin Seam Mining Operation

RIGHT: Section A-A of elevation below shows a layout of sublevels that is fairly common in the thin-seam operations along the Great Dike. The inclined hoisting shafts may be spaced as much as 1000 or 2000 ft apart along the strike of the seam. Vertical raises from the tramming crosscuts are at 40-ft intervals.





LEFT: This longitudinal section shows the development of the stope pattern at one property. Details of operation vary greatly from mine to mine, but resue stoping, similar to that used on the Witwatersrand, is widely used. Especially when applied to very narrow seams, this method tends to cut down efficiency and ventilation. The advancing method was dictated by lack of time for orderly development, as well as desire for rapid production with minimum working capital.

dip of the seam, and dump the ore into the car with a transfer of only a few feet. A hanging chute, made of iron, facilitates dumping the ore into the car without spilling. The ore contained in the short remaining pillar between the stopes and the upper haulage drift is mined by wheelbarrows upgrade.

Scrapers have been tried for handling both waste and chrome. While a conventional scraper operated by a small tugger hoist will handle waste, it frequently picks up too much waste matter when handling chromite. It was thought that a type of slide scraper could be developed that could be filled with chrome, or waste, and would then slide along the floor without picking up any further load. For waste handling, this scraper could probably be loaded in a conventional manner, but it appeared probable that hand loading would be better for chrome since it would avoid breakage and dilution.

This is the Impshi operation. Part of the plant and new compound buildings made of brick and galvanized iron are in foreground, while old compound is at distance in upper part of picture.

It is reported, however, that experiments with this type of scraper have not been too successful and that hand loading and the use of wheelbarrows is still largely standard practice.

Mining is carried on by resue stoping, that is to say, the chrome seam is carried in the floor of the stope. This method of stoping is similar to that practiced on the Witwatersrand. Waste is drilled and broken first, and as much waste as possible is used to make a dry pack wall to sustain the weight of the roof. Excess waste must be removed to the surface. The chromite is then carefully lifted, usually using hand tools with little or no powder, and moved to the surface.

Stopes are often carried only 38 in. high, sometimes as low as 32 in., and the dry pack supporting wall may be carried within 4 ft of the face. This tends to cut down efficiency and limit ventilation.

The chrome stopes are extremely narrow and the entire weight of the overlying formation is supported by a dry pack wall built as close to the working surface as convenient. This dry pack wall tends to compact, so the tramming drifts may be driven a little lower than the wall to prevent the car from jamming against the back. Pillars about 8-ft diam are also left on the upper side to prevent such subsidence. This procedure is almost exactly the reverse of similar operations in the U. S., where retreat is common, letting the ground come down on mined out areas.

The advancing method adds to the difficulties of mining but it has been dictated by the desire for production, and lack of working capital and sufficient time to drive out to the limits of the orebody and completely develop it for an orderly retreat.

Up to 1947, nearly all drilling was done by hand. Experiments were then started in the Umvukwe District, using reciprocating air drills and solid

tungsten carbide bits. These proved satisfactory and are now used extensively along the entire Dike. In 1949, experiments were begun with electrically operated auger type drills, such as are used in potash and coal mines. These drills have a tungsten carbide cutting edge and give very long life. It is understood that they are considered better, under normal conditions, than the reciprocating air drills and are being used increasingly throughout all the chrome operations.

Numerous variations in mining procedure are carried out at individual mines, but the above description should be detailed enough to give an idea of the way the work is carried on.

Transportation is Large Cost Factor

After the chromite is mined, it is transported in small cars or skips to the mine portal where it is stacked and measured. At this point considerable waste is sorted out to produce a high grade chromite product. The miners are often paid on the basis of these stacks, although they are guaranteed a minimum monthly wage. The chromite is then loaded into trucks and transported to a central point. Here it is again sorted and stacked for final measurement and sampling. Preliminary payment to the transport contractor is based on these measurements, although final settlement depends on rail weight. It is then moved to the railway by trucks which usually carry 10 tons and if road conditions permit, pull a trailer of like capacity.

Sometimes it is possible to stack the chromite close to the railway tracks and hence avoid rehandling it before loading. Often, however, there is so much chrome at the railhead it is necessary to stack the ore quite a distance away, causing additional handling. Thus, the chromite may be handled four or five times before loading on rail cars.

At one of the larger loading points, iron plates have been put down alongside the railway track for several hundred feet. A small scale was installed at one end of the 30-in. gage track, and cars holding about a ton of chromite are weighed on these scales and then pushed by hand and dumped on the plates. A careful record is kept of the dry weights involved, and an entire carload, approximately 40 tons of chromite, is piled on a given plate and is then shoveled into the railway car without reweighing.

To give an idea of the amount of handling involved at railhead, as many as 125 boys are required to take care of the loading of possibly 2500 tons of chrome a month.

The largest Rhodesian railway cars hold only approximately 40 tons of chromite. Each operating company has dump space at Beira and the cars are shunted to these dumps and unloaded by hand. At a later date the ore is reloaded, usually by diesel shovel, into cylindrical iron cans and these are loaded on the vessels by cranes. Sometimes these cans are put on lighters and taken out to the vessel; at other times they are put on railway cars, run up on the pier and discharged by cranes into the vessels. It can be seen that the chromite is handled from five to eight times after it is mined and before shipping and this handling is quite an item of cost.

Recently, however, it is reported that a new chrome wharf has been constructed at Beira, which utilizes conveyors and other modern handling methods. It is stated that it will be possible to load approximately 4000 tpd of chromite from this wharf when put in operation.

Beneficiation Plants

A large part of the chromite in Rhodesia is shipped as mined after hand sorting. However, at Selukwe, Spotts, and other points along the Dike there are concentrating plants for treating disseminated ores. Until 1950 the ores were crushed either by ball mills or stamps, and gravity methods such as jigs, tables and Humphreys spirals were used to produce a sand-like chromite concentrate. Since that date several modern mills have been constructed that combine the use of Heavy-Media separation, gravity methods, and flotation for the recovery of both coarse and fine particles of chromite.

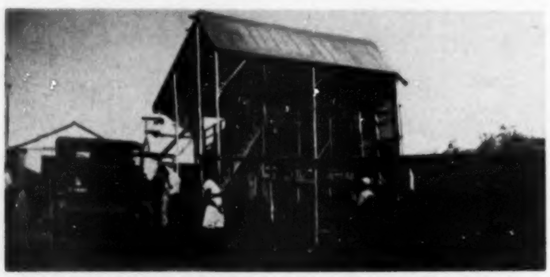
Since 1949, alluvial chromite ores have been processed. These ores are generally higher grade and have a better chrome-iron ratio than the disseminated ores. They can be mined by surface methods and concentrated without the necessity of primary crushing and at least one mill has been built to treat them. The product produced is exceptionally high in chromium and has an excellent chrome-iron ratio. It is stated that there is a good market for it.

A ferrochromium plant with a reported capacity of 600 to 900 tons per month has been erected near Gwelo. This plant, operated by a British concern, is using a patented French process.

Production Costs Show Rise

Discussion of operating costs is confined to underground production from the narrow chromite seams occurring along the Great Dike. None of the mining companies furnish cost data, and each property has special characteristics such as: distance from railhead, thickness of seam, local ground conditions, and labor supply, all of which materially affect its operating costs. It is believed that about 35 miles is the longest distance chromite can be economically hauled by truck except under unusual circumstances, such as a premium grade ore, or an exceptionally thick seam. The cost of such haulage is stated to be 8 to 12c per ton-mile. In addition, a variation of an inch in the thickness of the seam during mining will greatly alter costs, which therefore fluctuate widely from month to month.

Biggest factor in the cost of producing chrome ore from the Great Dike is the underground mining cost; followed in importance by the cost of moving the chromite from the mine to the railway, loading into the railway cars, and transportation to Beira. The railways charge a flat rate of about $2.80 per



The mill at Spotts is one of the earliest to be built in Southern Rhodesia for treating disseminated ores. It used stamps to crush the ore and tables for concentration. Since 1950, several modern mills have been installed.

Mine equipment varies greatly from operation to operation. Here, a steel headframe is in the process of being erected. Some properties depend upon hand tramming.

long ton for chromite from any point between Selukwe and Concession. North of Concession and south of Selukwe there is an additional charge of approximately 1.2c a ton-mile. Capital expenditure is also a very substantial item in Rhodesian production. The seams are so narrow that mining necessarily proceeds rapidly in a horizontal plane. In many cases less than 90 lb of chromite is produced from each square foot of area mined out. This requires large quantities of rail, pipe, and other mine supplies to keep pace with the rapid lateral advance of the stope faces. General overhead costs, on the other hand, are relatively low.

A monthly production of 3 to 6 tons per boy working underground with an overall average production of from 1½ to 4 tons per month for all the boys on the payroll is considered normal by the mines operating on the Great Dike.

Base wages for native labor in 1953 approximated $15.00 per month for miners; $12.00 per month for timbermen, and $10.00 per month for underground labor. In addition, lodging and food for worker and family are furnished by the employer.

In 1949, when the shilling was worth approximately $0.20 U. S. currency, the cost of chromite at dump Beira probably varied between 80 and 150 shillings per ton. Since that time, it is understood that wages, native food, and mine supplies have risen from 30 to 100 pct in terms of sterling. One producer, operating a thick seam close to rail, estimated he could deliver chromite at dump Beira in 1953 for about $15.40 per ton, an indicated minimum rise of about 40 pct in shilling costs. It is thought that the normal rise will approximate 50 pct. This increase has been partly offset, in terms of dollars, by devaluation of the pound, which is now worth $2.80 instead of about $4.00 U. S., as in 1949.

The breakdown of costs for one specific operation in 1949 was: mining, including supervision, 42 pct; transport of chromite from mine to Beira, 26 pct; capital expenditures, 30 pct; general overhead, 2 pct; total cost about 125 to 130 shillings per ton.

The various factors covering production and their relation percentagewise to the total cost may be summarized as follows. They will necessarily vary for each individual property and apply only to underground mines on the Great Dike.

Probably from 35 to 55 pct of the total cost can be charged to direct mining. Of this amount, possibly 40 pct is for direct wages, 20 pct covers such items as food, housing, and social benefits, and 40 pct is assigned for all other costs and supplies.

Costs of transport of the ore from the mine to Beira, including loading at the railway siding, probably accounts for from 25 to 35 pct of the total.

Capital investment, covering such items as rail, pipe, compressors, mine tools, and durable structures may come to between 10 and 20 pct of the total cost.

General overhead charges, including sampling charges and salaries of sample representatives at Beira, should be in the neighborhood of 5 to 10 pct. It can be seen from this that sudden fluctuations in the chrome market have a marked effect on the prosperity of Rhodesian chrome mining.

The Future: Reserves are Great

Chromite reserves of Southern Rhodesia are substantial. In the past it has sometimes been assumed that they could be calculated at so many tons per mile along the strike of the Great Dike and to this total could be added the tonnage at Selukwe. In the opinion of the writer, such an assumption is erroneous and may lead to reserve estimates that are not in accord with the facts.

In any calculations concerning chromite reserves, the following factors must be considered There are seven known chrome seams. In some parts of the Dike all of them may be mineable, while in other sections only one or possibly two can be worked. Their thickness varies, as does their chromium content, and their chromium-iron ratio. Furthermore, certain sections of the Dike are much more faulted and broken than are others, and these faulted sections can only be mined if the seam is exceptionally good. For all these reasons, long stretches of the Dike cannot be operated economically under present conditions. It is essential that each section be appraised separately before any estimate be made as to the chromite reserves present. However, recently published figures of 50 million tons appear reasonable and may well be exceeded when the mines are actually developed and worked.

The chromite industry of Southern Rhodesia is soundly established and financed. It operates on conservative and constructive lines and should be able to supply the nations of the world with large quantities of metallurgical chromite for many years to come.

The writer wishes to acknowledge the courtesy and cooperation of William C. Keeley, president of the Vanadium Corp. of America, in furnishing recent production information, and also to acknowledge the helpful suggestions of J. W. G. Mortleman of Southern Rhodesia.

Bibliography

[1] Chromium—Roland D. Parks, *Mining Engineering*, May 1952.

[2] The Great Dike of Southern Rhodesia—B. Lightfoot, *The Proceedings of the Geological Society of South Africa*, Vol. XLIII, 1940, pp. xxvii-xlvi.

[3] The Geology of the Selukwe Mineral Belt—H. P. Maufe, B. Lightfoot, and A. V. Zealby, *Southern Rhodesia Geological Survey Bulletin*, No. 3, 1919.

[4] The Geology of the Chromite and Asbestos Deposits of the Umvukwe Range, Lomagundi and Mazoe Districts—F. E. Keep, *Southern Rhodesia Geological Survey Bulletin*, No. 16, 1930.

[5] An Outline of the Geological History of Southern Rhodesia—A. M. McGregor, *Southern Rhodesia Geological Survey Bulletin*, No. 38, 1947.

[6] A Gravimetric Study Across the Great Dike of Southern Rhodesia—Otto Weiss, *Geological Society of South Africa*, Vol. XLIII, pp. 143-151.

Wet Phosphate Rock Storage and Handling

by George L. Lyle, Jr.

WITH the advent of World War II, the need for agricultural products rose phenomenally and caused a similar increase in demand for plant foods of which phosphate rock is one of the more important raw materials. By the close of the war or shortly thereafter, all of the operating companies were expanding their production facilities. Many companies installed modern bulk material handling facilities. Designs varied, but were generally of the overhead trestle type of storing conveyors. American Cyanamid studied these various installations but was not satisfied with the conventional system because of high initial cost, increased maintenance problems in the way of painting structural steel that might be submerged in stored materials, and because of slightly increased operating costs.

As a consequence of these economic analyses, conferences were held with the various conveyor manufacturers to develop a better method of storing and reclaiming. After considerable engineering study, one conveyor manufacturer suggested the unique system which was installed in 1950.

The Storage System

The storage system consists of the following elements: 1) A railroad spur with hopper building and car shaker; 2) A track hopper and vibrating loaders; 3) A 36-in. belt conveyor for elevating the material from the hopper to ground level; 4) A 36-in. swinging boom conveyor for stacking the material on storage; 5) A system of underground tunnels and conveyors to reclaim the material for drying and processing.

The track hopper is a completely housed concrete pit 20 ft deep which contains twin 50-ton feed bins for receiving the phosphate from 50-ton hopper cars. Suspended from the building superstructure is a 5-ton car shaker which can be lowered electrically to the top of each car to dislodge material and insure a complete unloading job.

Electric vibrating feeders under each bin are designed to deliver 400 LT per hr each, when elevated 12° from the horizontal and operating at full-load current. Feed rate is controlled by remote amplitude rheostat controls located on the operating panel at car dumping level. These controls enable the operator to adjust the vibration rate from zero to the maximum delivery rate. When pebble, +28-mesh material, is being unloaded, practically no vibration is required to secure a maximum belt loading, whereas, it may sometimes be difficult to completely load the belts with concentrates, −28-mesh material, when vibrating at the maximum rate.

These vibrating feeders discharge to a 36-in. stationary inclined belt conveyor which elevates the material from the hopper pit to 12 ft above ground where it discharges through a chute to a 36-in. conveyor belt operating on the boom stacker.

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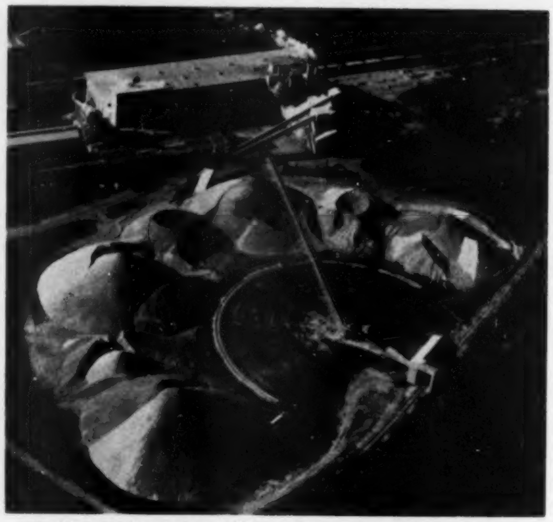


Looking northwest from 600-ft altitude, the wet rock storage plant is in foreground, with drying and grinding plants in background. Diagram on next page identifies storage plant elements visible here.

The boom stacker, most unique part of the system, which consists of a steel truss carrying a 36-in. belt and its driving mechanism, is pivoted at one end and inclines upward so that the head end is about 90 ft above ground level. The truss is supported near the mid-joint by a network of two laced steel columns which travel on a semicircular standard gage railroad track mounted on a concrete foundation. This provides a rigid travel way for the stacker boom. Each of these columns terminates on a group of four trucks which are propelled by a 7½-hp motor controlled from the operator's panel in the track hopper house. Each unit is also equipped with solenoid brakes for stopping the stacker at the desired location as well as track clamps for anchoring the stacker in case of storms or long periods of idleness.

Phosphate is fed on the fixed end of the stacker conveyor and discharged over the head end to one of several storage piles. Storage is in a semicircular pattern of separate piles which resemble a kidney shape when viewed above. The stacker stores on a centerline radius of 270 ft, giving 320,000 tons gravity storage capacity. Additional capacity may be secured by the use of a kicker and/or tractor dozer to move the material away from the discharge point.

The boom conveyor is driven by a 125-hp electric motor through a fluid coupling and tandem pulley

arrangement located near the main tail pulley. It is controlled from the operator's panel in the hopper house. Belt takeup is of the constant gravity type and is fully automatic. Because of the angle of incline and heavy belt loading, the system is equipped with a solenoid, rachet type, hold-back.

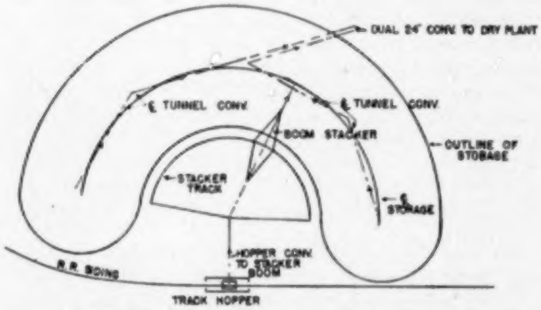
The operator controls this complete system from the hopper house. He notes the grade in each car to be unloaded and spots the stacker so that it discharges to the corresponding grade on storage. In order to speed unloading, the yard master and train crews endeavor to group their cuts of cars so that as much of one grade as possible is unloaded at one time. Since the boom stacker is geared to a linear movement of 15 fpm it is important to unload as much as possible at each location so as to conserve unloading time.

The Reclaiming System

Located beneath the point of discharge of the boom stacker are a series of reinforced concrete tunnels 1025 ft in length. The tunnels are rectangular in cross-section, have their top at ground level, and are arranged as chords to the semicircular arc subscribed by the boom stacker discharge. In order to reclaim from any point on the storage and in any combination of grade, all reclaiming conveyor tunnels are brought together at the center of the storage pile. Contributing conveyors from either side of the semicircle are capable of delivering up to 300 LT per hr each. From this center point, two 24-in. conveyors, each with a capacity of 300 LT per hr, move to and above ground level to discharge through multiple gates and chutes to the two 24-in. inclined conveyors which feed the three rotary kiln dryers. At the point of transfer to the conveyors feeding the dryers, feed from any section of the storage can be crossed to either of the belts feeding the dryers.

Roofs of the underground tunnels are provided with cast iron double undercut clamshell type bin valves which are located at 8-ft intervals. These gates are provided with manual controls so that any quantity up to a complete belt loading may be introduced to the belt from any point on the system. Each conveyor is provided with several rail mounted moveable feed hoppers. These hoppers are designed to ease the impact of the falling material on the belt and at the same time provide an automatic means of stopping the feed material should the conveying system stop for any reason. This second purpose is accomplished by designing hoppers so that the angle of repose of the material is reached before the hopper is full.

By varying the bin valve openings under several different grades of storage, any desired composite



General layout of the wet phosphate storage area.

Stacker boom slanting over a pile at one end of the storage area is most unique part of system. Good layout and intensive conveyors provide complete storage flexibility.

grade can be blended within the range of the maximum and minimum grades currently in storage. This is important in phosphate operations since sales contracts vary widely and mining conditions may produce many different grades within one 24-hr period.

All conveyors of the reclaiming system are controlled by the drying plant operators. All are interlocked electrically and may be operated from any point on the system simply by reaching and pulling a cord which parallels the entire system just above the operator's head.

In order to operate the storage at maximum efficiency, i.e., by gravity reclaiming, a minimum quantity of 150,000 tons must be available at all times. Whenever the storage falls below this level, a tractor dozer must be used to move the material to and over the bin valves supplying the reclaiming conveyors.

Economic Comparison

Prior to the installation of this system, cars of rock of the desired grade were shoved up an incline track over a wet bin feeding the dryers. Only five cars could be handled at one time, and, since the drying plant was operating on a 24-hr basis, this necessitated a locomotive being operated on the same basis. Whenever the mines produced more than could be dried or wherever a grade was produced for which there was no immediate demand, it was necessary to unload this surplus with ¾-cu yd clamshell draglines to ground storage. This was reclaimed by reloading with small dragline when needed and the method was not only costly, but it was exceedingly difficult to control shipping grade.

The more important advantages of the new system over the old are: 1) More uniform control of grade by blending while storing and reclaiming; 2) Elimination of the use of the small and inefficient ¾-yd draglines for storing and reclaiming excess production; 3) Mine operation is not slowed down; 4) Operation is more balanced by being able to store different grades as they are mined and hold them until needed; 5) Delay of railroad equipment is eliminated by increasing dumping capacity and cars are released before demurrage charges are incurred; 6) It increases the work output of the locomotive by eliminating considerable switching, thus enabling one locomotive to do all dumping of wet rock in 8 hr of each day.

The installation of this system reduced the direct material handling costs by about two thirds, as well as giving a flexible system that enables the company to service customers promptly and efficiently.

What Influences Students to Choose Mining

This survey reveals why students choose mining—and why they don't—The analysis of how to be effective in reaching the student provides ammunition for future campaigns to bolster lagging mineral industry enrollment.

by John J. Schanz, Jr.

THE highly publicized shortage of students enrolled in engineering curricula has brought about a rapid increase in the enrollment in engineering schools in many parts of the country. Though most of the various curricula in the mineral industries field have participated in this increase, the experience at Pennsylvania State University has been that the nonmineral types of engineering have been increasing at a much more rapid rate than those in the College of Mineral Industries.

Freshman Enrollment—Pennsylvania State University

	1950	1951	1952	1953	'50 vs '53
College of Engineering	237	564	758	819	345 pct
College of Mineral Industries	87	99	126	128	147 pct

It has been a matter of some concern to the staff of the College of Mineral Industries that enrollment in the curricula of the school has not been increasing at a rate commensurate with that experienced in the College of Engineering. If the lack of trained young graduates for our vital mineral industries is to be overcome, this situation must be remedied.

It was deemed essential that information be gotten to young high school students approaching college age of the unequaled opportunities and national necessity for young men to pursue careers in the many diversified parts of the mineral industries. The question of paramount importance was how best to accomplish this task.

The author was given the job of determining through a survey of the current freshman class in the College of Mineral Industries what had influenced them to enter one of several fields of study offered by the school. One of the key questions to be answered, if possible, was why the shift from a high percentage of veterans in the immediate postwar period to an enrollment of predominantly recent high school graduates in the last two years had caused a severe decline in the number of students taking the more highly specialized or lesser known curricula such as fuel technology, mineral preparation, geophysics, and mineral economics.

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MINING & METALLURGICAL MANPOWER

Last February Leo F. Reinartz, President of the AIME, expressed grave concern about the shortage of mining and metallurgical engineers. Since then . . . William B. Plank, in MINING ENGINEERING for May (p. 496) . . . reviewed the situation statistically . . . they take no comfort in the present situation and express genuine alarm over future prospects. Of the 519,000 professional engineers reported in the 1950 census, about 5 pct were in mining and metallurgy. Of the engineering students in the class of '53, only 3.8 pct were in mining and metallurgy—a scant 900 of the 24,189 graduates. Analyses of the 1954, 1955, and 1956 class enrollments have shown that the percentage drops to 3.1 (1954), 2.3 (1955), and 1.6 (1956).

From the *Newsletter* for July 6, 1954, issued jointly by the Engineering Manpower Commission of EJC, and the Scientific Manpower Commission.

It is believed that the results of the survey will assist materially in increasing the effectiveness of the college's future program in disseminating career information to prospective students. Since undoubtedly the same situation is being faced by mining schools throughout the country, the results of the Penn State survey, covering 117 first semester Mineral Industries students, are summarized here.

It is apparent from the data that the family is by far the most important center of influence on the high school student's choice of both a curriculum and a school to attend. Personal contacts made by alumni and literature distributed by the college are of some importance in helping the student to choose a curriculum, but are slightly more significant when it comes to choosing a school to attend. Considering the fact that 72.6 pct of the students surveyed said that they had received special career counseling, the effectiveness of high school counselors is remarkably low.

An examination of that data indicates that the first thing a student will consider in picking a curriculum is how good his chances will be for getting a job. He is also frequently interested in whether or

not he will work in an office, in a laboratory, in a mine, or out in the field. Salary and social status of his future job seem to carry little weight with the freshman contacted.

Of particular importance in planning a campaign to encourage more high school graduates to enter into mineral industries training is the effect of the prospective student's local environment on his choice. The figures indicate conclusively that the type of industries the student sees near to his home or his father's job are not too important in his choice and may even have a negative effect on the student. Almost half of the students studied are following careers not common in their home community. Furthermore, though fathers may influence their sons' choice of a school and profession, their influence apparently is directed toward encouraging them to enter some field of work other than what the father followed.

High school career advising has been of little help in encouraging students to follow careers in the mineral industries. One of the main reasons for this is apparent from the data shown in the last table. Though the quality of the guidance given was generally good, only 52.9 pct of the students received any information on professions in the mineral industries. Furthermore, in only 14.1 pct of these cases did the counselor go beyond a mere mention of these career opportunities. This condition no doubt exists as a result of the lack of information possessed by the high school adviser who may be a teacher of English, history, or some other unrelated subject. Rather than ignore the counselor, a greater effort must be devoted to making certain that they are fully informed and incapable of ignoring the opportunities in the mineral industries.

(Ed. Note: One booklet providing a picture of opportunities in mining and related fields is "Careers in the Mineral Industries," published by the AIME. Another example is the booklet just issued by the Div. of Mineral Technology, University of California, Berkeley, called "Unusual Careers in Engineering—Mining, Metallurgy, Petroleum, Ceramics.")

It is indicated by the data developed in this survey that every effort must be made to increase the interest in mineral industries careers of not only the students, but also the parents. This means that information preferably must reach the hands of the students and in some manner actually enter the homes of the students. One means of doing this, which has been employed far too little, is through the *popular* type of family literature. Presentation of talks to groups such as Parent Teacher Associations and Rotary Clubs would provide another way of assuring contact with parents. On the other hand, catalogues, and similar type of material sent to high schools, probably all too frequently end up in high school libraries and on the desks of high school career counselors where the effectiveness is at a minimum.

Whatever avenues of approach are used in getting information to students, parents, and counselors, this information will probably be most effective if it stresses the number and variety of jobs that are awaiting the young graduate from our mining schools. Moreover, the dissemination of literature, the presentation of talks, the participation in high school "career nights," all of these, should be accomplished with the realization that local industry does not tend to limit the sphere of interest held by the student or parent.

The Students Choose

HOW

Source of Greatest Influence on Students' Choice of Curriculum and School

	Influenced Choice of Curriculum, Pct	Influenced Choice of College, Pct
Father or member of the family	34.2	35.9
Personal friends	13.7	7.7
College students or alumni	13.7	21.4
College publications	12.8	14.5
High school counselors	9.4	12.8
Members of the profession	3.4	3.4
Miscellaneous literature	6.0	0.9
Indefinite answer	6.8	3.4

WHY

Characteristic of the Profession that had the Greatest Influence on the Students' Choice of Curriculum

Reason	Pct
Good opportunity for getting a job	47.9
Liked the environment the profession offers	26.5
Were familiar with the profession	7.7
Liked the part of the country where they would work	6.8
Felt they had a special aptitude	4.3
Were attracted by the salaries offered	3.4
General attractiveness of the profession	3.4
Desired the social status that accompanies the job	0.0

WHO

Qualitative Correlation between Student's Choice and His Home Environment

	Definite Relationship, Pct	Good Probability of a Relationship, Pct	Very Little Probability of a Relationship, Pct
Correlation between industries found in the student's home area and his choice?	18.1	33.6	48.3
Correlation between father's profession and his choice?	16.4	4.3	79.3

WHEN

Analysis of High School Career Guidance

	Yes, Pct	No, Pct	
Students receiving career guidance	72.6	27.4	
	Excellent	Good	Inadequate
Quality of guidance received	17.7	64.6	17.7
	Extensive	Limited	None
Mineral Industries career data included in guidance	14.1	38.8	47.1

How One Company Appraises Management Development Programs

Do the intangible benefits balance the tangible costs? This company finds the answer definitely is YES

by Carl E. Reistle, Jr.

ENGINEERS as a group are often criticized because they have been responsible for the development of many technical improvements only to allow the administration of them to pass into the hands of others who may have little understanding of how they operate and little competence in their use. These criticisms are not always justified. There are many engineers who have shown themselves to be great administrators in addition to being great creators or builders, and more and more one sees the engineer demonstrating unusual administrative ability as he moves into the executive ranks.

The last five or ten years have seen a new movement developing in this country—a movement brought about through the recognition by business statesmen that successful business administrators and executives just cannot be expected to develop like Topsy, that the management of a company must deliberately take steps to cultivate the proper climate or environment for growth if it wishes to provide an adequate and capable succession of executives in the future. This movement has taken on a number of names—Management Development, Executive Development, Personnel Development—but are these not actually misnomers? Can we develop anybody? In the strictest sense of the word, the author doubts that anyone can change any other person, at least, not much. The change must come from within. Perhaps this movement should be looked at not as a program of developing people but as one of giving people an *opportunity* to develop themselves. In the Humble Oil & Refining Co. there is an Executive Development Program; maybe it might better be called a Program of Development for Executives.

One of the first acts of Humble's original board of directors in 1917 was to set aside capital stock of the newly formed company for purchase by employees, the idea being to make them partners in the business and to encourage career employment. To further this objective the company has also followed a policy of promotion from within, deviating from it in only a few instances. If this policy is to be carried out and if the company is to be successful in its operation, it is obligatory that there be maintained within the company a climate that will stimulate and promote the growth of executive talent.

It has not been easy to do this, as during the 36 years of corporate life there has been a broadening of all industry and a specialization of functions, the like of which the world has never known. The petroleum industry has certainly been no exception to this and, with its many and varied activities requiring highly trained specialists in each of them, presents today a vastly different environment to its executives than it did to their predecessors at the turn of the century. Employees, through no fault of their own, find their work confined to a highly specialized function and when they attain managerial status, are often unable to look on overall problems with the broad perspective required of managers. Thus, it is exceedingly difficult for executives in large corporations to gain through normal experience acquaintance with the many company operations essential to their satisfactory functioning as top-level executives. This has been the experience in our company, particularly in the case of technical and professional men; and it is also experienced by most engineers.

Recognizing this situation, the company in 1946 set up an Executive Development Program. This was a first attempt to formalize a process that had been going on, after a fashion, in all departments of the company for many years. Broadly speaking, this program consists of appraising abilities of those in executive positions, determining the prospective replacements for such positions, and then providing opportunities for growth and development to those who are considered outstanding. One of the purposes of the program, as stated, is "to establish a uniform system of development and training throughout the company which will assure an adequate supply of potential executives with a broad background of experience." Or putting it another way, the company was setting up a formalized program to make generalists out of specialists.

Within our company it is possible to give executives experience in all phases of its operations and to supplement this experience by individual coaching; but a need was felt for something additional which would give these men a broader concept of the administrative function, a recognition of the impact of outside influences on business itself, a better understanding of the role of business in our economic and social systems, and time to reflect upon all of these factors as they are related to our company operations. The company did not feel it was able to do as good a job in these respects as desired, and was aware of the good work that the Harvard School of Business Administration was doing with its Advanced Management Program and so, in the spring of 1947, the comptroller was sent to attend the program and evaluate it for the company. As a result of his enthusiastic participation in the program and upon his favorable recommendation, the company has continued to send executives to every subsequent session. They, too, were of the opinion that the program was of real value and to date 30 Humble executives have attended subsequent sessions. The company would have liked to have sent others in addition to these 30, but because

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Human values show in executive comment

been a broadening of horizons and recognition of the rights and aspirations of individuals

the words "tolerant" or

a better understanding of human emotions and the vital part that they

"tolerance" in attempting to describe of the need for statesmanship in business

greater participation in civic and community affairs. And whether or not

of the great demand by other companies for places in the program it has not been possible to do so.

When word came out about similar programs being offered by other universities, they, too, were investigated; and as a result, the company is now participating in the programs of Columbia University, Northwestern University, the University of Pittsburgh, Stanford University, and the University of Houston in addition to the Harvard program. The participants in these programs have given the same enthusiastic reports as given by those who attended the Harvard program, and so today the use of these short intensive courses has become a regular part of the company's Executive Development Program.

Experience shows that those who attend these courses find it difficult to make a clear-cut evaluation of them, especially immediately upon their return to their jobs. They are of the opinion that in a general way the courses have been of value to them; but all of them find it difficult to state specifically, especially to someone else who is unfamiliar with the program, how they have benefited. It has apparently been an experience which they think has been of real value to them, but nevertheless hard to explain. Probably after a year their thoughts and ideas begin to jell sufficiently so that they can begin to explain their feelings in words that convey meaning to others.

The author had the privilege of attending Harvard's Advanced Management Program six years ago. Upon returning to his job he experienced the same difficulty as others in expressing views about the benefits he had derived or could expect to obtain from the stay of 13 weeks there. But now, with the lapse of six years, the benefits the program afforded can be seen rather clearly. Last fall a questionnaire was submitted to the 33 men who attended these various programs prior to 1953. This assured that each would have at least one year of retrospect in which to appraise the program he attended. These ideas concerning the benefits they derived are based on the answers they have given to this questionnaire.

First of all, there has been a broadening of horizons and in some instances an opening up of new horizons. Operations outside of one's own department have attained a new significance and the importance of these operations to the company effort as a whole assumes new proportions. There has been a greater appreciation of the need for statesmanship in business and there is a real desire on the part of people who have attended these courses to measure up to the demands for such statesmanship. Coupled with this has been a more enlightened recognition of the rights and aspirations of individuals working with the company and a real attempt to take these rights and aspirations into consideration when setting up new policies and implementing older ones.

Too often the engineer is prone to look upon the technical and factual side of the problem and when he has worked out his answer, conclude that that is all there is to it. Too often he fails to realize that many of the people in his company without his background, training, and experience do not think as he does, that their attitudes toward the solution of the problem may not be as objective as his, that emotional factors of people must be taken into consideration in addition to the technical or factual aspects of the problem, and that because of his failure to consider these emotional forces quite often many of the people in the organization will not readily go along with the solution. Many technical people who have attended these programs acquired a new method of approach when dealing with administrative problems and they seem to show a better understanding of human emotions and the vital part that they play in any organized activity.

Not only have horizons been broadened but in almost every instance attendance at one of these courses has had a direct and definite effect on work procedures. Nearly all say that they have developed to some extent a more objective approach in the making of decisions, and a willingness to proceed a little more slowly so that the opinions of others and as many facts as possible can be brought to bear upon a problem. Many speak about the need for separating facts from opinions and the patience that is required to do this. Some speak about the overall job of being a manager and the need for anticipating and defining problems before they arise. All of these changes in attitudes should go far in helping these executives develop into capable administrators with real leadership skills.

Undoubtedly all of you have noticed the emphasis placed by many of our country's industrial leaders on the importance of business executives participating more actively in community and civic affairs, and it is unfortunate that so many business men do not understand the need for such participation. Who can say how valuable such participation can be for any company; not so much with respect to the additional business it may gain for itself, as for the generation of a suitable climate in which it can live and carry out its objectives? More than one fourth of the executives who have attended these management development programs say that there has been awakened in them a realization of the need for greater participation in civic and community affairs. And whether or not they recognize this need themselves, it can be observed that nearly all of them, after their return from one of these programs, begin within a short time to show a greater interest in these outside affairs than they had ever shown before. This is of such value to the company that it alone may well be worth the time and money spent.

The good that accrues to industry in general as a result of the impact on the university faculties by the business executives who attend these programs should not be overlooked. Most of the faculty members who work with these executive development programs also teach in the undergraduate and graduate schools of the universities, teach our own sons and daughters, teach the sons and daughters of our employees. Quite often one hears the criticism that university faculties do not have enough contact with business, do not see the practical side of business problems, are too idealistic and live only in a world apart from the actualities faced daily by business men. These criticisms are not necessarily true, but the exchanging of ideas by business men and faculty members in the classrooms of these programs and on the campuses between class periods will do much to bring about a better understanding by faculty members of the problems of business and the effect that Government policies and regulations will have on business. Thus, programs like these play a great part in helping to develop a better climate in which industry in general is able to operate.

The questionnaire submitted to our executives asked: "What changes have you noticed in yourself as a result of attending the program?" Three fourths of the answers to this question might be grouped under the heading Greater Tolerance, and it is interesting to see that almost half of these specifically used the words "tolerant" or "tolerance" in attempting to describe changes that they themselves have experienced. Since one of the objectives in our executive development effort is to make generalists out of specialists, it seems to me that even if a spirit of tolerance is all that a person acquired from one of these programs, we would have to consider the program as being worthwhile.

The cost of sending an executive to one of these programs is not low. It represents a real investment in time and money, as he is away from his work for a period of 4 to 13 weeks. Then, too, it is not easy for an executive in the 40 to 55 age bracket to leave home for several weeks and go back to the academic life, nor is it easy for his family to adjust themselves to his absence. In addition to the salary he receives while attending the program, there must be added the cost of tuition, travel back and forth, and living expenses while he is away. All of these add up to several thousand dollars for each individual, and so it is not surprising that the executives hesitate to say positively that they have profited sufficiently from the program to justify the company's expenditure in sending them. But perhaps this is modesty because nearly all of them point out benefits they have received, which should repay the company well for the investments that have been made; and in addition, they are unanimous in stating that the company should continue to send others, provided they are properly chosen. However, there is one definite advantage in sending an executive away for several months that offsets the disadvantages, and that is the opportunity afforded the company to give someone else actual experience in his job, not as an observer but as one who is given the opportunity to carry out the functions of the job and make the decisions, the opportunity to make mistakes and profit from them, and the responsibility of being held accountable for his decisions and actions. Of course, this is an opportunity which can be developed through other means, but it is one that the company has been able to use advantageously.

Now, what are some of the debits in the management development programs? Frankly, with the exception of absence from the job and from home and the matter of cost, all of which have already been mentioned, there are very few. And these few vary in individual cases, depending upon each person's own likes and dislikes. One person might criticize the way the course in Marketing is put on but at the same time speak in laudatory terms about the course in Human Relations, while another will say that he benefited a great deal from the Marketing course but did not care too much for the professor who conducted the discussions in Human Relations. Some say that the course is too long, that the last week could easily be dispensed with, while others say that to shorten the schedule would weaken the course. Naturally, there will be some objections to any of these programs, since it is impossible to suit the individual likes of all who attend them.

It has been the practice in nearly all of these programs for each class to make frank comments to the faculty, designed to help them improve their program. And it has been by observation that when a preponderance of the participants are unfavorable toward a certain course, methods of instruction, or an instructor himself, steps have been taken to improve the situation. But where criticisms come from only a few and are based mainly on the personal situation, they have not been considered as justification for making changes. It is my opinion that this is the correct way of treating comments from the group; and the universities are to be commended for standing fast in meeting their objectives, even in the face of some criticism.

Naturally, it is not feasible to ascertain all of the benefits from these programs that have accrued to each of the executives who has attended, and elaboration of detail on the advantages already mentioned has been avoided. Perhaps the Humble Oil & Refining Co.'s position can best be summed up by stating that it thinks so well of these programs that it is continuing to send executives to them.

However, it should be pointed out that no university has a panacea for all the ills of management nor do all of them follow the same method in approaching the problem of helping management. Each of them is trying to utilize the resources it has available to it and is not necessarily imitating the methods used by others whose resources are different from theirs. And attending each program there will be a group of executives participating just as diligently and just as enthusiastically as other groups in other programs to get all of the possible good out of the program.

Also, it should be suggested that not too much should be expected from those who attend, as all do not respond or react equally. The petroleum industry knows that only one out of every nine wildcat wells drilled finds oil and that the producing wells vary widely in potentiality and production. So it is with executives who attend these programs. Not everyone will get what it is hoped he would, but some will and from these the company will be repaid many times for the investment made.

If the opportunity arises to attend one of these programs, by all means take advantage of it. If the opportunity is not open to you, then find some way on your own initiative to broaden yourself along the lines suggested by these programs so you will be better equipped to take over broader administrative duties and advance in your organization.

A Milestone in Subsurface Exploration

The NX Borehole Camera

by E. B. Burwell, Jr., and R. H. Nesbitt

Designed by army engineers, the NX borehole camera provides the most economical method of subsurface exploration so far devised. Continuous cylindrical color photographs now reveal minor flaws in foundation bedrock not always disclosed by borehole samples. A unique projector transforms the photographs into true-to-scale images of three dimensions.

A NEW milestone in the progress of photography and subsurface exploration was reached when the Chief of Army Engineers announced the development of the NX borehole camera. In obtaining continuous undistorted cylindrical color pictures of dry or water-filled borings the device surpasses all other cameras designed for photographing interior surfaces of pipes, wells, and conduits.

The usefulness of the camera and the unique projector that comes with it are at once apparent. To the geological, mining, and civil engineer alike it signifies the end of guesswork with respect to underground conditions that have eluded identification by conventional core-drilling methods. To the medical profession it may well signal new progress in photo optics which could result in cylindrical color photographs supplementing the X-ray and existing photographic methods used in exploratory surgery.

The pilot model of the camera has more than paid for itself as a result of its success in bringing to the surface at two dams information previously obtainable only by costly drilling of mansized boreholes for subsurface on-the-spot examination. Such bores cost as much as $200 per lineal foot as against $10 per ft for the conventional 3-in. or NX exploratory core borings from which the present invention derives its name. The NX camera can now photograph completely the interior surface of these borings.

Research and development for the first camera and projection equipment were conducted by Engineering Research Associates, Division of Remington Rand, Inc., under the technical supervision of the Geology and Geophysics Branch, Office of the Chief of Army Engineers in Washington, in accordance with plans and specifications furnished by this branch. Subsequent modifications of the camera-lowering device, transporting equipment, and special field tools were made in the Corps of Engineers' Ohio River Division Laboratories in Cincinnati. The background of this development is interesting.

Among the more difficult foundation problems involved in construction of concrete dams are those resulting from bedrock imperfections that escape disclosure by conventional exploration methods. Often these imperfections are of sufficient magnitude to introduce costly changes, especially when their presence is discovered only after foundation excavation is well in progress. Bedrock flaws most frequently camouflaged may be ruptures resulting from the enormous stresses to which rocks have been subjected, or they may be planes or zones of weakness related to chemical alteration and underground erosion. Obviously, detailed information on their location, dimensions, and structure is important, as these factors can affect the stability of a dam and the security of life and property downstream. Their discovery and appraisal entail extensive subsurface exploration.

At present the most economical exploratory tool available to geologists and engineers is the small-diameter diamond core drill by means of which cores of the foundation bedrock are recovered for examination and testing. All too often, however, these samples fail to disclose minor foundation flaws that may be of major importance before a structure is completed. As a result, the small-diameter drillings are supplemented generally by more reliable but much more costly shafts, tunnels, or large-diameter calyx drill holes that permit the investigator to examine the foundation rocks in place. It was to reduce the number and cost of these expensive and time-consuming investigations, as well as to obtain more complete information on rock structure from the smaller borings, that the NX borehole camera was developed. That it has been eminently satisfactory in accomplishing that purpose is demonstrated by its success most recently at the Folsom dam, under construction on the American River, 23

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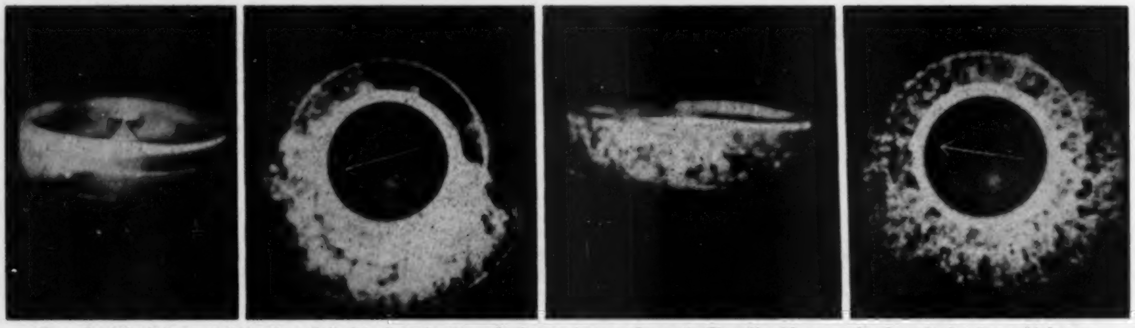
Discussion on this paper, TP 3831AI, may be sent (2 copies) to AIME before Oct. 31, 1954. Manuscript, March 10, 1954. New York Meeting, February 1954.

The Transactions papers appearing in Mining Engineering during 1954 will subsequently appear in AIME Transactions Vol. 199 and may be permanently referenced to that volume.



Figs. 1a-1d (left to right): 1a—Cylindrical projection of picture image shown in Fig. 1b. Note peak of conical prism which refracts plane images to three-dimension pictures on the cylindrical screen. Fig. 1b—Similar to Fig. 1d. Shows plane image projection of a faulted and fractured section of granite at a shallower depth in the same boring. Fig. 1c—Cylindrical projection of the picture image shown in Fig. 1d. Approximately one-half natural scale. Fig. 1d—Borehole camera picture of a blue-gray granite in central California. Picture, with the open center containing a compass arrow, represents a 360° conical image of the interior surface of a 3-in. boring. Approximately one-half natural scale.

miles upstream from Sacramento, Calif. Here some seventeen 3-in. boreholes, drilled to penetrate a fault zone in the granite at depths of 50 to 75 ft below the foundation, were completely photographed in kodachrome. Representative black and white reproductions of these kodachromes are shown in Figs. 1a to 1d. In addition to locating and photographing the fault zone precisely, the pictures recorded delicate changes in rock coloring, fractures as small as 1/100 in., and the surface of the groundwater table. A compass, visible in each picture, see Figs. 1b and 1d, permitted orientation of all these features on a

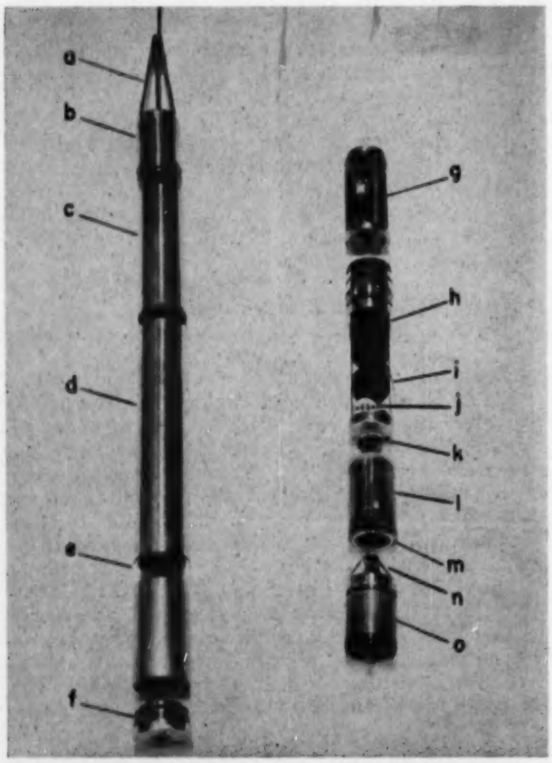


Fig. 2—A view of the NX borehole camera showing external elements of camera tubing on left, internal elements on right. (Tapering of lefthand figure is due to off-center position of photographer's camera.) Reference letters are covered in the text.

unique cylindrical projection screen. Since the materials in the fault zone were too soft to be recovered completely by the small-diameter core drill, their investigation and the extent of the fault as a whole could be accomplished only by tunnels, shafts, and costly mansized calyx borings. The camera came to the rescue in time to eliminate the proposed calyx borings by producing faithful color-picture records of all 17 small-diameter holes. Previously the camera had been used successfully in locating cracks in the spillway of a high concrete dam and in photographing bedrock texture and structure in dam foundations in Virginia and Pennsylvania.

Externally the camera unit, shown in Fig. 2, is a simple stainless-steel tube, length 31½ in. and diam 2¾ in., with a circular quartz window *(e)*, not unlike a miniature lighthouse window, located 5 in. above the lower end. Internally the principal elements include an oil-damped compass *(o)* which supports a hollow and truncated conical mirror *(n)*. The mirror is situated inside and directly opposite the quartz window and thus comprises the eye of the camera. The hollow and truncated construction of the conical mirror makes the underlying compass visible to the 15-mm camera lens *(k)* located a short distance above the mirror. A high-voltage circular flash tube *(m)*, midway between the cone mirror and camera lens and actuated by a current pulsing device on the camera lowering rig, simultaneously illuminates the boring and exposes the film to the bright mirror image. Directly above the lens is a conventional 16-mm motion picture camera *(h, i, j)*, with motor and spool drive synchronized by the same pulsing circuit which actuates the flash tube. A power condenser and relay unit *(g)* contacts the top of the camera unit. The camera is designed to make 16 flash exposures per ft of boring. Thus with a 1-in. section of drillhole exposed at each flash and with 16 exposures per ft of boring, sufficient overlap from picture to picture is obtained.

Suspending the camera from the ground control mechanism is a three-conductor cable, armored externally by reverse-lay preformed steel wire which prevents cable twisting. The tensile strength of this cable is 2700 lb.

On the ground surface the camera is controlled by a lowering device, Fig. 3, which consists of a pay-out reel *(c)* with a capacity for 500 ft of camera cable, level-wind control *(b)* for the cable guide reel *(h)* geared to a 16-notch pulsing wheel and depth counter

(*i and j*), and a hand-crank and gear drive (*g*) to the cable pay-out reel for lowering and raising the camera. Attached to the lowering mechanism is a small power supply cabinet (*a*) which transforms 117 v ac to three dc circuits of 450, 50, and 50 v, respectively. The highest voltage is transformed to 15,000 v in the flash tube circuit of the camera; one 50-v circuit is connected to the camera motor drive and synchronizing relay; the other 50-v circuit provides the synchronizing pulse. When a film is completely exposed, the individual pictures are projected and studied as a series of separate still photoflash images and not as a moving picture film.

Pictures are taken during the ascent or retrieving of the camera, in as much as cable tension is more constant and the motion of the camera steadier. A dummy camera of the same weight and dimensions is lowered and retrieved before the real camera is risked in the boring. Since the camera pulsing wheel is geared into the crank and gear-drive of the cable reel and guide reel, the time interval between picture exposures is controlled by the speed at which the hand crank is turned. Best results are obtained when the exposure interval is 2/3 sec. With a capacity for 25 ft of 16-mm film, 75 ft of boring may be photographed continuously before reloading is needed.

The camera is designed to withstand a hydrostatic head of 500 ft. Pictures obtained in dry and water-filled borings are equally good.

All the camera equipment is portable into any site where diamond core-drilling equipment can enter. With the aid of temporary cribbing and leveling screws (*d*) attached to the frame, the ground-control mechanism can be leveled and made ready for operation a few minutes after the equipment is uncrated at the site. A portable 117-v ac gasoline generator supplies the necessary electric power when other sources are unavailable.

No less unique than the camera, from the standpoint of optics, is the device that was developed to project the continuous and overlapping pictures obtained by the camera. This unusual projector transforms the pea-sized doughnut-shaped images, which the camera's cone mirror impresses on the film, into true-to-scale cylindrical images. This is three-dimension picture projection in its truest sense. The

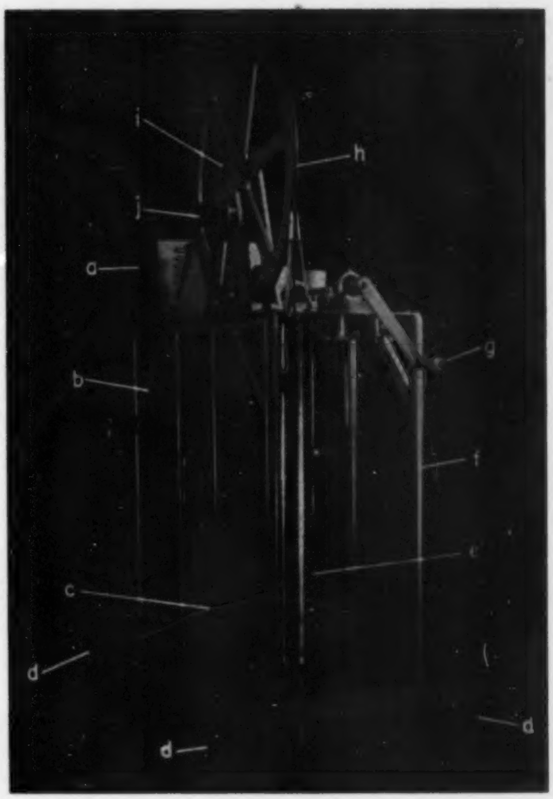
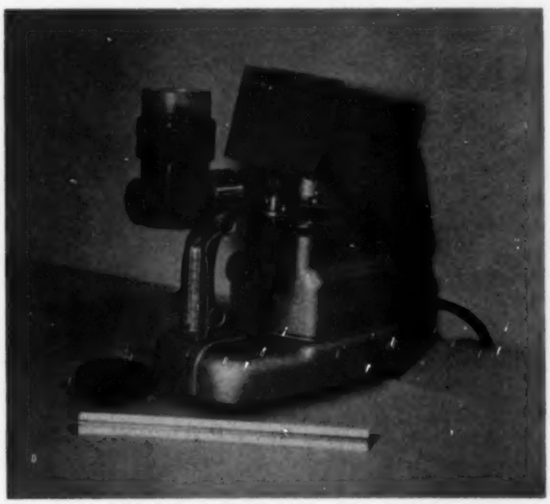


Fig. 3—The borehole camera machine, showing control frame *f* and camera proper *e* ready for photographic operation. Note cone mirror near lower end of camera tube. Camera tube diam is 2¾ in.

cylindrically projected image simulates a 1-in. section of the inside of the boring. Each picture presents accurately the depth, orientation, and dimensions of every feature of the rock and, on color film, discloses much information as to its composition, texture, and soundness. The advantages of the pictures over the rock cores are that 1—conjecture re-



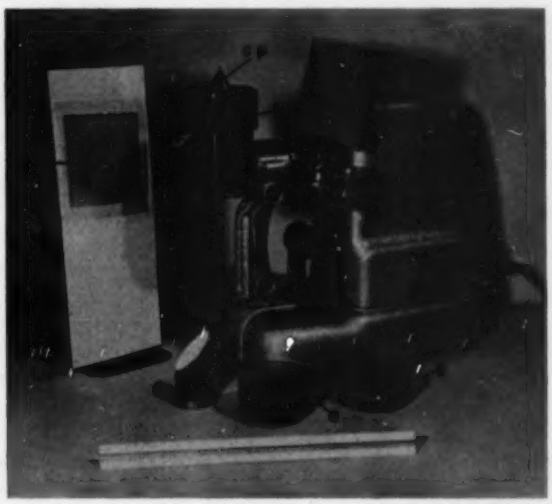


Fig. 4 (right)—This borehole camera projector is used to view transparencies taken by the borehole camera, which photographs a 360° arc of the walls of a 3-in. drillhole. Fig. 5 (left)-The same projector, with 45° plane mirror, *c*, and cylindrical ground-glass screen, *a*, removed for plane image projection on screen, *h*. Reference numbers are covered in text.

garding core losses is eliminated, and 2—the orientation (dip and strike) of faults, fractures, contacts, bedding planes, and other structural features of the rock can be determined easily and accurately.

The cylindrical projector, as shown in Figs. 4 and 5, is a converted Viewlex 35-mm projector, adapted to support either the conventional 5-in. lens for large plane-image projection or the L-shaped projection tube developed for combined cylindrical-image and small plane-image viewing. A 500-w lamp supplies the required light. In cylindrical projection, light passes through the small circular image on the film and is projected by the lens to the 45° plane mirror (*c*) at the base of the vertical arm of the L tube (*l*). The inclined mirror in turn reflects the circular image upward to a clear-glass conical prism (*cp*), slightly larger than the cone mirror of the camera. By refraction the prism transforms the plane image into an inverted cone of light intercepted by a surrounding frosted-glass cylindrical viewing screen (*a*) of the same diameter as the original boring. The picture is inverted on the film spools before projection so that it may be viewed in proper orientation on the screen.

Compass orientation of the cylindrical image is obtained by lining up the north arrow visible at the top of the conical prism, Fig. 5, with 0 degrees on the adjustable azimuth ring at the base of the viewing screen. The trend and inclination of fractures or bedding planes in the rock can be measured quickly by a straight-edge and protractor. A counter *d* geared into the right-hand film spool *f* records the correct depth of each picture. Thus while the camera transforms a section of the interior of the borehole into a plane image on the exposed film, the new projector reverses this process by transforming the plane image into its original cylindrical form.

A most convenient feature on the new projector is its adaptability to plane-image projection. Retracting the inclined mirror from the aperture (*ca*) projects a true-scale inverted plane image of the boring to a flat screen, see Fig. 5. This projection is merely an enlargement of the small picture on the film. It is used exclusively for editing the film strip, since every feature of consequence to the geologist can be detected rapidly before special sections of film are subjected to detailed study on the cylindrical screen.

To assist the reader in visualizing the relationship between the plane and cylindrical images, attention is called to the diagrams, Figs. 6a-6c. Fig. 6a is a core specimen of granite gneiss obtained from a drillhole along the Rappahannock River, Fig. 6b is the borehole camera film image of the section of the boring corresponding to the bracketed section of the core, and Fig. 6c is the cylindrical projection of the plane image. In all three figures, *J* is a prominent rock fracture paralleling the lamination of the rock, while *f* is a secondary branching fracture. While the composition and soundness of the rock could be ascertained readily on Fig. 6b, the trend, inclination, and dimensions of the fractures could be viewed in their undistorted relationships only by the cylindrical projection, Fig. 6c.

Fig. 6a (right)—Segment of 2⅛-in. core of granite gneiss. Fig. 6b (center)—Borehole camera film image of section of 3-in. boring from which core was extracted. Fig. 6c—Cylindrical projection of film image. Bracket on 6a shows depth range of 6b and 6c.

Assuming that both pieces of rock core below the fracture *J* were lost during drilling operations, the geologist examining the core might conclude logically that either a sizable void occurred at this elevation or that the rock was too highly disintegrated to permit complete sample recovery. The new borehole camera would solve the problem immediately by disclosing the type and structure of the rock at this point and the precise direction and slope of the two sets of fractures responsible for loss of the core sample.

The Chief of Army Engineers is continuing research designed to improve the efficiency and versatility of the camera and the projection device.

Corrections

In the April 1954 issue: TP 3768B. Flotation of Oxidized Zinc Ores. By M. Rey, G. Sitia, P. Raffinot, and V. Formanek. On p. 420, col. 2, under Conclusions, the first sentence should read as follows: **After six** years of study in the laboratory and three years of mill operation treating more than 10,000 tons of ore, it is held that flotation of oxidized zinc ores by the combination of sodium sulphide and primary amines is an efficient process and well under control.

In the May 1954 issue: TP 3743B. Flotation and the Gibbs Adsorption Equation. By P. L. de Bruyn, J. Th. Overbeek, and R. Schuhmann, Jr. On p. 520, col. 1, Eq. 4 should read as follows: $\Sigma_i\, n_i\, d\mu_i = 0$

Change to Rotary Blasthole Drilling in Limestone Increases Footage, Cuts Time, Saves Manpower

by D. T. Van Zandt

IN the late 1920's rotary drills began to replace the churn drills in the petroleum industry, but until the middle 1940's the churn drill was the only widely accepted means of drilling large-diameter blastholes for quarry operations.

The Calcite plant of the Michigan Limestone Div., U. S. Steel Corp., was one of the first to experiment with rotary drills for quarry blasthole drilling, and the first to employ compressed air on a fully rotary rig to cool the bit and raise the cuttings to the collar of the blasthole.

The Calcite plant operates a limestone quarry near Rogers City, Mich., in the northern part of the lower Michigan peninsula. The formation quarried, a portion of the middle Devonian series, is the Dundee limestone, which is uniform, seldom massive, and characterized by definite bedding planes. The dip is southeast, 40 ft to the mile. Quarry faces vary from 20 to 116 ft in height. Vertical blastholes are used entirely, from three to five rows of holes being drilled parallel to the working face, spaced 18 ft apart with 18-ft burden and drilled 6 to 8 ft below shovel grade. Quarry operations coincide with the navigation season on the Great Lakes, as the bulk of the stone is transported by lake carrier. The normal operating season runs from April to December, the remaining time being devoted to stripping operations and plant and equipment maintenance.

In the following discussion drilling rates mentioned refer to overall drilling time and include all operations such as moving from hole to hole, penetration and extraction of tools, and routine maintenance. Time consumed by such factors as power delays and major machine repair is not included in drilling time unless otherwise stated. Figures cover only operations at this one plant in the formation mentioned. Needless to say, a very different set of figures could be obtained in a different formation. However, the comparison of footage obtained with churn drills and rotary rigs in this particular formation has been used as an indication of what might be the expected performance of rotary rigs in other formations.

Prior to 1950 the bulk of the blasthole drilling at the Calcite plant was done by electrically powered churn drills. Both crawler and wheel-mounted rigs were used. These machines, which mounted a 22-ft drill stem of 4½ in. diam and a spudding type of bit 2 to 4 ft long, drilled a hole of 5⅝-in. diam. Average drilling rate of these rigs in the Rogers City formation was 8½ ft per hr.

In 1946 one of the first rotary blasthole drills offered to the quarry industry was put into use on an experimental basis. This machine, known as the Sullivan Model 56 blasthole drill, Fig. 1, was on 16-in. crawler pads and electrically powered at 440 v. The drill bit, a Hughes Tri-Cone roller bit of 5⅝-in. diam, Type OSC, was threaded into the end of the 4-in. square hollow drill rod or stem. These drill rods were 20 ft long with female threads on one end and male on the other to allow for addition of the desired number of rods for drilling holes of various depth. Rods were handled by a single drum hoist geared to the main drive motor and racked by a 30-ft derrick or mast when not in use. The cable from the hoist drum fed through a crown block on the top of the derrick back to the water swivel mounted in the top end of the drill stem in use. This cable remained attached during drilling operations and was used to hoist the tool string from the hole. Down pressure was applied to the tool string by means of a pair of 4-in. diam hydraulic cylinders acting on the drill chuck holding the drill rod. The first chuck consisted of flat jaws which gripped the flat sides of the stem. These jaws were controlled by set screws forcing them into contact with the drill stem. As these set screws had to be loosened and tightened by hand with each stroke of the hydraulic feed cylinders, there was great delay. For this reason the semi-automatic chuck was developed which automatically gripped the stem on the downward stroke but released for retraction of the hydraulic feed cylinders. Rotation was imparted to the tool string by a rotary table acting on the chuck and geared to the main drive motor through a separate gear train and clutch. A positive displacement water pump, mounted on the drill, fed water through a system of pipes and hose into the water swivel mounted on the top of the drill rod and through the rod and bit, washing the drill cuttings to the collar of the hole. Where water was scarce, provision was made to settle out the cuttings coming from the collar of the hole and re-use the water. Where water was abundant the stream coming from the hole was wasted. Drilling rate with this machine was about 20 ft per hr and bit life 1600 ft of hole.

While this rate was more than twice that obtained with the churn drills employed, the problem of water supply and drill cuttings disposal rendered the machine impractical from an operating standpoint. Consequently it was used only in that part of the operation for which water was easily supplied, when the character of the formation made it least difficult to wash cuttings away from the collar of the hole.

In October 1949 it was suggested that drill cuttings be removed by compressed air, long used for this purpose on pneumatic drills, and collected at the collar by suction. Thereafter, the water pump on the Sullivan 56 was replaced by a 500-cfm air compressor and a trial run made. Air pressure at

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the water swivel was held between 30 and 50 psi and rotation varied from 35 to 105 rpm. Pressure of 500 psi was maintained on the hydraulic feed cylinders. The same bit as that used with water was employed, a Hughes Tri-Cone of 5⅝ in. diam. Several holes 40 ft deep were drilled.

Because the equipment used was cumbersome to move, during these first tests the points checked were primarily penetration rate and bit life. Penetration with a new bit proved to be 15 in. per min or 75 ft per hr. With water the penetration rate had never been more than 38 ft per hr. After penetration rate had been carefully checked over 24 hr of drilling time the tests were temporarily stopped. At this point the bit showed little sign of wear; the bearings were in very good shape and the teeth only slightly worn.

Because of the favorable results obtained thus far, it was decided to remodel the Sullivan 56 for permanent use. Calculations by engineers of Hughes Tool Co. showed that an air velocity of some 3000 ft per min should be maintained in the drillhole to raise the cuttings successfully and constantly offer a clean surface to the bit. As the bearings in a 6¼-in. Tri-Cone bit were more suited to the operation, this size was recommended and the orifices modified to give better cooling to the bearings and to keep the bottom of the hole clean.

Following the recommendations of the Hughes Tool Co. and the Joy Mfg. Co., a 365-cfm Joy air compressor and a rotoclone, Model 8 D, manufactured by the American Air Filter Co., were mounted on the Sullivan 56 drill and the tests continued. By use of orifices in the bit, the only means of throttling the air flow, an operating pressure of 68 psi was maintained at the swivel. Down pressure on the tool string was varied from 400 to 650 psi, or a maximum of 11,000 lb weight on the bit, and rotation was varied from 35 to 105 rpm. Best operating conditions

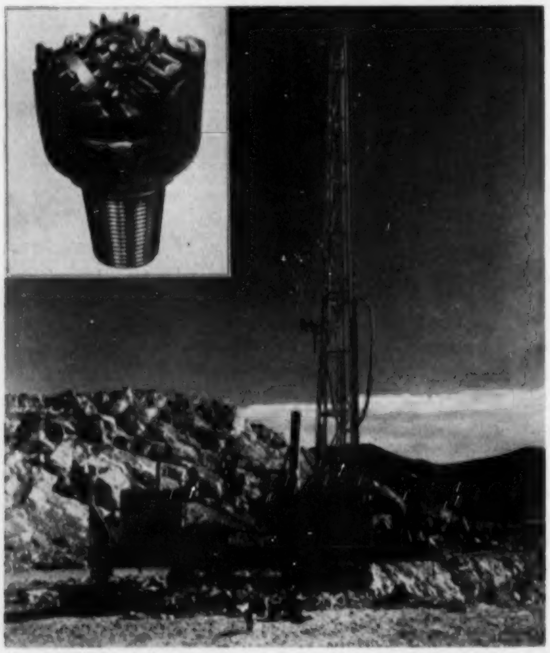

Fig. 1—First rotary rig tried was of same type as the Sullivan 56 shown here. Drill was remodeled to incorporate 365-cfm compressor and rotoclone. Inset: Type OSC Tri-Cone rock bit furnished by Hughes Tool Co. for rotary blasthole drilling.

Fig. 2—The Sullivan 58, above, weighs 25 tons, handles 30-ft instead of 20-ft rods, and has 48-in. feed.

were found to be at 80 rpm and 500 psi down pressure. With a new bit the drill was operated for 137 hr under these conditions, moving time included. Total footage drilled during this period was 5227 ft, an average drilling rate of 38 ft per hr, collar to collar. Penetration rate with 100 ft of hole on the bit was 75 ft per hr. At 5227 ft of hole on the bit, penetration rate had dropped to 42 ft per hr. At this point the bit was carefully inspected. The bearings were in fair condition, all cones turning freely but feeling rough. The teeth showed considerable wear but not serious loss of gage.

The bit was replaced with a new one of the same type and testing continued under the same conditions. Bit life of 4905 ft was obtained after a period of 130 hr of operation. Bit condition was essentially the same as that of the bit previously run.

During the latter part of the period the Sullivan 56 was being tested and modified at the Calcite plant, the Joy Mfg. Co. developed a heavier drill built around the same general principles as the 56, but with several major modifications. This drill, known as the Joy 58, weighed about 25 tons as compared with the 12 tons of the 56. This newer type, Fig. 2, used either diesel or electric power. The chuck on the new rig was located in the center of the machine rather than at the end so that the weight available to the tool string, applied through a pair of 6-in. diam hydraulic cylinders, could be about double that applied to the 56. A 40-ft mast or derrick allowed the use of 30-ft drill rods instead of the 20-ft sections standard on the 56. The new rig was also crawler-mounted, and in addition carried three hydraulic jacks for use in leveling the drill. The derrick was also raised and lowered hydraulically. A modified semi-automatic chuck operating over a 48-in. feed range replaced the 30-in. feed range of the 56. Controls were in the operator's cab located back of the chuck. This cab was so arranged as to give the operator clear vision of all operations. A 365-cfm air compressor was mounted on the forward end of the drill, replacing the water pump originally carried. A Model 8 D rotoclone on the side of the machine collected the cuttings from the collar of the hole, drawing them through an 8-in. flexible hose and discharging them alongside the drill. The machines operated at the Calcite plant carried a bank of 4000/440-v transformers behind the operator's cab. The transformers were Y-con-

nected with grounded neutral and instantaneous breakers, as is general practice in the quarry. Lighting was on 110 v through a separate dry-type transformer. Each machine was equipped with 1500 ft of No. 6, three-conductor, rubber-covered trailing cable which tied into the 4000-v quarry system.

Four of these machines were purchased by the Michigan Limestone Div. for use at the Calcite plant in March 1950. The drills were put into use immediately following their delivery. While these machines were in general similar to the Sullivan 56, the added weight available to the tool string led to considerable experimentation to find the best operating conditions. Extensive tests conducted by the Hughes Tool Co. proved the penetration rates shown in Fig. 3 to be possible. Bit life was found to be a function of bit bottom time and pressure.

Taking into consideration penetration rate, bit life, drill maintenance, and overall drilling rate, a pressure of 550 psi at 86 rpm was found to give best overall results. Under these conditions the collar-to-collar drilling rate, based on records covering four 9-month operating seasons on the four machines, was found to be 45 ft per hr with an average bit life of 3800 ft.

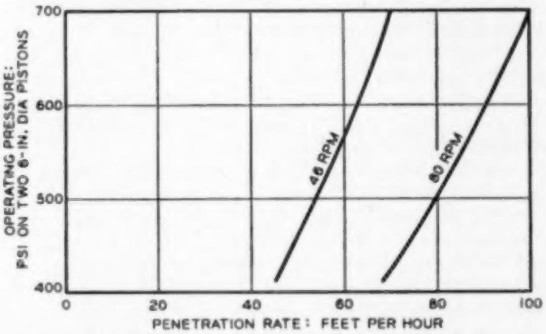

Fig. 3—Variation of penetration rate with down-pressure at various operating speeds.

Previous to the purchase of the rotary drills, the drilling at the Calcite plant was done by churn drills. In the years of 1948 and 1949 the drilling requirements of this plant were slightly over 500,000 ft of blasthole per operating season. To obtain this footage 16 churn drills were operated 16 hr per day during the operating season and five drills operated 8 hr per day during the stripping season. During the years 1950 through 1953 an average of 615,000 ft of blasthole per season has been required. Employment of four Joy 58's and one Sullivan 56 drills 16 hr per day during the operating season has supplied this footage. The operators of the new machines had used churn drills for an average 23 years and averaged 51 years of age. Their breaking-in period on the rotary drills was supervised over a one-month period by a Joy service engineer. During the four years the drills have been in operation the drilling department has not had one lost time accident on the rotary machines.

Because stripping operations completely remove the overburden and loose stone from the limestone being drilled, there has been very little experience of drilling loose or unconsolidated material at the Calcite plant. During the time the churn drills were in use steel casing was used in all holes, sometimes to a depth of 20 ft. No casing is used in the rotary drillholes, even in the softest formations. Where the collar is loose, cardboard casing 2 ft long is inserted after the drill has moved off the hole. This is done mainly to assist the blasters in loading the holes, as the casing furnishes a smooth collar through which to load. No attempt is made to reclaim the casing.

Some water is encountered as drilling grade in some areas lies 6 to 10 ft below the local water table. In drilling these areas the hole generally remains dry as long as the air stream through the tools is maintained. If there is occasion to cut off the air when the bit is below water level the hole fills with water in 2 to 5 min. During this time it is possible for cuttings to be forced up into the body of the bit. To prevent this, a screen is located in the bit to keep the larger particles from entering the air jets serving the bearings. When drilling is resumed the water and mud are blown to the collar of the hole. Under these circumstances it is found inadvisable to use the dust collector as the moist cuttings block the passages to the suction fan.

During freezing weather and also when the humidity is very high there has been difficulty in keeping the passages through the dust collector clear. Several access doors were added to the standard rotoclone to facilitate cleaning when necessary. When drilling is done during freezing temperatures antifreeze solution introduced to the air stream beyond the compressor receiver prevents freezing in the dust collector.

Calculations have shown that an air velocity of some 3000 fpm must be maintained within the blasthole to raise the cuttings to the surface successfully. Experience at the Calcite plant has shown this to be true with a 6¼-in. bit mounted on rods 4 in. square with a penetration rate up to 75 ft per hr. Where penetration rate is higher than this, it is possible to make cuttings faster than they can be removed and a stuck tool string is the result. When this occurs, down pressure must be reduced to zero and rotation and blowing continued. If this does not free the tool string, the tools may have to be raised during rotation, possibly by a combination of hydraulic pressure and hoist cable.

It is to be noted that the overall drilling rate with the Joy rotary drill is about half the actual penetration rate. This is due to several factors, i.e., moving from hole to hole, leveling the machine, retracting the chuck over the available feed, adding drill rods, removing drill rods, and lowering the machine upon completion of the hole preparatory to moving to the next hole. In addition to these operations there is the routine maintenance such as lubrication. These factors and the time they take have been included in the drilling rate figures quoted and amount to about half the available time in a shift. It has been proved that in any given formation under set conditions of rotation and weight on the tool string, penetration rate will remain constant. To increase the overall drilling rate the time, motion, and labor involved in getting the bit on bottom and actually drilling the hole must be decreased. It is encouraging to the quarry operator to see that several companies are attacking this problem. At the Calcite plant it is seen that with rotary drills more feet of blasthole are being drilled in less time with fewer men than were being drilled with churn drills. The advent of the rotary drills is the first major change in large-diameter blasthole drilling in some 30 years. Progress is by no means at an end. With the developments now in sight it is quite possible that in the space of a very few years the present rotary rigs will have become as obsolete as the churn drills.

Relationship of Geology to Underground Mining Methods

by George B. Clark

Many basic engineering principles of all four phases of mining operations, namely, prospecting, exploration, development, and exploitation, can be analyzed better in terms of quantitative geology. Geological data from both field and laboratory will also complement scientific methods now being developed.

THE geological data emphasized so successfully in prospecting for new deposits, that is, structural controls, strength of solutions, and type of mineralization, are basically those required for successful exploitation. In the mining of newly discovered deposits the most economical methods should be employed as early as possible to keep the overall cost per unit produced at a minimum and to permit maximum extraction of valuable minerals. A crucial question is: How can geological data be translated into useful quantitative results which will aid in achieving this end?

H. E. McKinistry[1] has suggested that a solution may be reached in one of two ways: 1—the usual approach, use of judgment based on experience; or 2—mathematical calculations and tests on models, both subject to certain limitations. He also suggests that in addition to better use of geology more case data and theoretical data are needed on which to base sound judgment. Further research, therefore, is necessary. Perhaps in this field the emphasis should be on more specialization in mining methods and ground movement by men with thorough training in physics, engineering, geology, and underground mining. These specialists would be equipped to point out the most economical and scientific methods of exploitation.

Selection of a stoping method is governed by the amount and type of support a deposit will require in the process of being mined, or by the possibility of employing the structure of the deposit to advantage in mining the ore by a caving method.

In addition to these factors there are others which almost invariably influence the choice of an economical method of mining:[2] 1—strength of ore and wall rocks; 2—shape, horizontal area, volume, and regularity of the boundaries of the orebody, and thickness, dip and/or pitch of the deposit and individual ore shoots; 3—grade, distribution of minerals, and continuity of the ore within the boundaries of the deposit; 4—depth below surface and nature of the capping or overburden; and 5—position of the deposit relative to surface improvements, drainage, and other mine openings.

In the final analysis it is usually necessary to disregard the less important of these factors to satisfy the requirements of the more important. Because of the variation of geological conditions throughout and surrounding the deposit, no mining method will be everywhere ideally applicable to the conditions encountered in one ore deposit.

The immediate problem is to interpret the above physical characteristics of deposits in terms of geological characteristics. Very few quantitative geological data are available on the factors related to a choice of mining methods. However, there are many descriptive data in mining and geological literature which collectively show how important an effect details of geology have upon all phases of mining operations.

The following categories of basic mining methods were investigated to establish the geological factors that have affected their successful application: 1—open stopes with pillars; 2—sublevel stoping; 3—shrinkage stoping; 4—cut-and-fill stoping; 5—square-set mining; 6—top slicing and sublevel caving; and 7—block caving. It should be noted that the first five of these methods are listed in the order of increasing support requirements. Mines were selected as examples only where geological descriptions were complete enough to warrant their use.

A study of the geological factors involved in mining operations led to a choice of the following classifications, employed in Table I: 1—structural type of orebody; 2—dimensions (geometry); 3—country rock (type); 4—faulting, folding, and fracturing; 5—alteration of ore and rock; 6—type of mineralization; and 7—geological factors determining mining method (summary). Of these factors only one yielded results that can be defined from available data in a quantitative manner, i.e., dimensions of the deposit.

These are the most reliable guides that can be used in selection of suitable mining methods. They are, in general, the properties of geologic structure most difficult to evaluate by studies of models, photoelastic studies, and other laboratory methods, all of which are at present more limited in their applications than the geologic method. Application of geology has proved a reliable guide in other phases

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of mining and requires only an extension of basic principles for application to stoping operations.

Geologic data for 52 mines were compiled, tabulated, and analyzed. Table I illustrates the method of tabulation. The mines listed are not, of course, necessarily representative of all those employing a given mining method.

Three examples, one of which is given under the classification of open stopes in Table I, were taken as representative of bedded deposits amenable to open-stope mining with pillars. They are noted for simplicity and strength of structure, competency of the beds, absence of extensive faulting, and absence of destructive alteration. In spite of the fact that dimensions of the deposit are variable, the open-stope method has uniform application throughout the deposits as long as the ore and rock are strong enough to support large openings. The placing of pillars is governed almost entirely by the presence of minor faults, fractures, or weak beds. Where these planes of weakness do not occur the pillars may be spaced regularly. It is noteworthy that many deposits may occur in sedimentary rocks which have been metamorphosed. In the case of the deposits in the Tri-State district, the rock was strengthened considerably by the presence of silica which resulted in the conversion of the limestone to chert and flint. In most cases the bedding planes, although inherently weak in sedimentary rocks, did not cause problems of support unless they were accompanied by faults and fractures.

Mine openings in shale almost invariably require timber. If water is also present the shale becomes muddy, having the consistency of soft clay. If it is dried out by dry currents of air in the mine atmosphere, it tends to slough and spall.

Water courses are also consistent sources of trouble. Even if they are dry they represent planes of weakness. If they are active, they create pumping problems.

Sublevel Stoping

Employment of the sublevel method of stoping requires, among other characteristics, a strong ore which will serve as a strong roof and offer safe footing for men and equipment on benches that have been undercut by mining. Massive sulphide ore which has not been subjected to fracturing or alteration processes such as oxidation is almost ideal for this type of mining. The sulphide minerals seem to have a capacity for filling small fractures as well as large ones, providing a mineral complex, even in complete replacement processes, which is very competent and strong. The healed fractures vary from those of microscopic size to faults and even cavities of fairly large dimensions.

Strong walls are found in rocks of all three genetic types. Fine-grained rocks are generally very competent, even when slightly fractured. In all the examples studied there is a remarkable lack of extensive post-mineral faulting, fracturing, and alteration processes that weaken the rock structure.

The large size of the ore deposits is a desirable feature, even in the case of the massive and irregular lower H orebody in the Horne mine, where the sulphide ore itself often constitutes the walls of the stope. In the case of this deposit, the silicification of the rhyolite breccias has played an important part in strengthening the enclosing rock structure.

Shrinkage stoping is classified by some as an open-stope method of mining and by others as a supported stope method. Each classification is probably justified because the back of the stope, which is usually ore, is unsupported during the process of mining, while the walls are supported by broken ore whether they need immediate support or not. Deposits mined by this method are on the borderline between those that require support during mining and those that do not. In terms of strength of ore and walls, this must mean that the ore should be strong in any case, while the walls may be weaker than the walls of deposits mined by sublevel stoping.

A study of 14 mines shows that there has been little if any significant destructive alteration of the ore or rock, but there is more evidence of dynamic movement of the rock in the deposits mined by shrinkage stoping, especially some post-mineral faulting.

In some cases, as at the Hollinger and Wright Hargreaves mines, the size of the veins was the determining factor, only narrow veins being mined by this method. At the United Verde mine a massive sulphide body, non-ore, serves as the host rock for the ore deposits. Unless disturbed by faulting and fracturing it is very competent, as are similar bodies (ore) at Tennessee Copper Co. (sublevel stoping).

Cut-and-Fill Stoping

Cut-and-fill stoping is employed successfully in those deposits that display a degree of structural weakness just one step further removed from those that are strong and accessible by shrinkage methods. It is common to find both these methods of mining used in the same mine to extract the ore from different sections of the same deposit. Many mines use three methods of mining in the same deposit, that is, square-set stoping in addition to the two noted above.

Cut-and-fill stoping requires relatively strong ore that will need no support during stoping operations. It is used to advantage where the ore is strong but the walls so weak that shrinkage methods cannot be used without causing dilution of ore.

The geological reasons for use of cut-and-fill are summarized as follows:

1—Weakening of rock structure by pre-mineral faulting.

2—Weakening of rock structure by post-mineral faulting.

3—Further weakening of rock by hydrothermal and hydrometamorphic processes.

4—The absence of silicification in certain areas of a deposit.

5—The absence of other types of healing mineralization.

6—Irregularity of outline of deposit, which requires a selective method of mining.

7—Irregularity of grade or lack of uniformity of grade of ore, which also requires a selective method.

8—Rapid oxidation of ore, preventing use of shrinkage stoping which *stores* ore in stopes for long periods of time. This is true for ore that is to be treated by flotation where oxidation of sulphides interferes with the flotation process.

The factors affecting the use of square-set mining are as follows:

1—Grade of ore must be high enough in grade to pay for the large amount of timber required.

2—Physical character of ore and rocks. In nearly all the mines using this method the enclosing rocks are broken and altered. Structurally weak ore and rocks usually go together, although this is not always the case.

3—Size, shape, and dip of deposit. The method is

Table I. Geological Factors Affecting Mining Operations

Method and Mine	Structural Type of Ore Body	Dimensions	Country Rock	Faulting, Folding, Fracturing, Etc.
Open Stopes with Pillars Southeast Missouri	Nearly horizontal bedded deposit	Thickness 7 to 200 ft, width 800 ft, and length 1200 ft	Dolomitic limestone (Overburden 300 to 500 ft, limestone and shale)	Few important faults
Sublevel Stoping Horne mine, Noranda, Que.	Large, irregular nearly vertical body of massive sulphides, occurring as a replacement of brecciated rhyolite	H orebody: length 600 ft, width 40 to 450 ft	Rhyolite, brecciated	Faults of small displacement and shear zone-faults are of varying intensity
Shrinkage Stoping Hollinger mine, Porcupine, Canada	(See last column) Veins along fractures	Widths to 75 ft	Altered and distorted igneous and sedimentary rocks: Greenstone, porphyry and pillow lava schistose parallel to strike of veins	Post-mineral faults of small displacement. Considerable dynamic action has caused distortion, shearing, and schisting
Cut-and-Fill Stoping Creighton mine, Ont., Canada	Lenticular deposits in shear zones in norite and granite	Up to 1000 ft long, 300 ft wide. Dips: 35° to 60°	Norite hw, and granite fw	Brecciation caused by pre-mineral faulting
Square-Set Stoping Tintic Standard, Tintic district, Utah	Replacement ore—sulphides and oxides in massive limestone beds	Massive, 20 to 200 ft thick	Limestone, shales, and quartzite	Intense pre-mineral and post-mineral faulting
Top Slicing Blueberry mine, Michigan Marquette Range, Michigan	Tabular type deposit, nearly vertical	Average width 50 ft, length 200 ft. Dip: 75° to vertical	Slate fw, cherts, and jaspers	Pre-mineral folding and faulting
Sublevel Caving Gogebic Range, Eureka Asteroid mine, Michigan and Wisconsin	Concentration of hematite in pitching troughs formed by intersection of dikes with fw quartzite or impervious slates	Irregular in shape from few to several hundred feet in width and thickness; from several hundred to several thousand feet in length	Hw-bands of slate and partly leached cherty iron formation, breaks into slabs which tend to arch	Numerous faults of all strikes and dips
Block Caving Climax mine, Climax Molybdenum Co. Climax, Colo.	Top portion massive and dome-shaped; bottom portion elliptical ring	Elliptical section 3000 ft and 2800 ft on two axes. Mineralized zone or ring 400 ft wide. Capping: 0 to 300 ft	Silicified schist, granite, and early porphyry Rock classed as: 1—Very strong 2—Moderately strong 3—Moderately weak 4—Very weak	Hard granite cut by fractures Orebody intensely fractured by post-mineral and pre-mineral faulting in places

very flexible and can be used in almost any size of deposit regardless of its shape and dip.

4—Effect of ground movement. There may be some settling in the fill, and there is squeezing and subsidence of country rock.

5—Availability and cost of timber, labor, and rate of oxidation.

6—Safety of mining operations.

The square-set method is the one usually employed when other methods, exclusive of caving, fail to satisfy conditions for safe mining.

For both top slicing and sublevel caving methods of mining, the most necessary requirement of the structure is a weak capping that will cave when it is undermined. This feature is found in almost all examples studied and is due either to the presence of weak members in the overlying formation or to the presence of planes of weakness. In any event the caving formations should not *key* and arch to such an extent that sudden collapses will create dangerous mining conditions. Top slicing is more adaptable to deposits of large horizontal extent,

Table I Continued

Alteration of Ore and Rock	Type of Mineralization	Geological Factors Determining Mining Methods
Little local alteration	Disseminated galena in limestone and shale	1—Flat bedded deposit —simple geometry 2—Simple undisturbed structure. Few faults and fractures 3—Strong ore and competent rock
Silicification of breccias Sericitization: limited to areas where it does not critically affect mining Chloritization	Sulphides carrying Cu and Au ore is unusually strong and compact in character and stands well Occasional slips in ore; little gangue material	1—Silicification of breccias strengthened rocks 2—Massive sulphide ore has but few slips and is very strong 3—Ore does not oxidize easily before flotation 4—Little effective weakening alteration of country rock or orebodies
Dynamic alteration of rocks	Quartzite, pyrite, Au fracture patterns determine strength of the ore	Only minor post-mineral faulting and hydrothermal alteration Shrinkage stoping used only in veins thinner than 8 ft and with strong walls
Pyritization-sulphides have cemented some breccias	Massive and disseminated sulphides in morite and granite	Cut-and-fill used where: 1—Weakness due to shear 2—Irregular orebodies 3—Rock bursts in granite 4—Pressure due to depth of mining operations 5—High-grade ore requiring selective method
Intense hydrothermal alteration and oxidation of both ore and limestone in and near deposit	Lead-silver ore, sulphides, and oxides	Intense fracturing, alteration and oxidation weakened structure so that immediate support is required. Previous methods also weakened overall structure.
Some country rock metamorphosed to chert and jasper	Hematite ores, secondary concentration in brecciated zone of iron bearing sediments	Top slicing used in wide ore, otherwise mined by sublevel stoping Capping caves readily; ore is strong enough to stand temporarily
(?)	Concentration of hematite in pitching troughs	1—Triangular shape of orebodies causes capping to cave slowly 2—Soft weak ore 3—Fairly strong capping which slabs when unsupported but delays caving temporarily
Sericite slips in granite Silicification intense at fw to slight at hw Capping shows surface alteration and less silicification	Molybdenite in fractures and dissemination in quartz veinlets	Massive orebody and capping are fractured and altered and weak enough to cave. Weakness due to both post-mineral and pre-mineral faulting. Ore occurs in very weak to moderately strong rock, all of which may be caused to cave.

while sublevel caving can be employed to mine deposits more irregular in outline. In both cases the ore should be moderately weak, but strong enough to stand temporarily. This characteristic may be due to the inherent character of the mineral complex itself or to alteration and fractures.

Iron deposits in the Great Lakes region are amenable to extensive application of one of the above methods, both because of the character of capping and the geometry of the deposits.

The work of King at the Climax Molybdenum[8] mine is one of the few published attempts to evaluate the strength of mine rock in a quasi-quantitative manner. The strength of the rock and the ore are defined in terms of the spacing of fractures, type of mineralization in the fractures, and silicification and alteration of the constituent minerals. The original composition of the rock and the type of alteration are also important. Silicification and kaolinization together almost universally indicate weak rock structure. Strength and composition of mineralizing solutions, pre-mineral and post-mineral faulting, and composition of the local rock all contribute to strengthening or weakening the rock structure.

At Climax the rock formations are strong as compared with those of other block caving mines. However, the relative positions of the four classes of rock, together with the fact that the ore is not very strong, make the deposit adaptable to block caving methods.

In the *porphyry coppers* the alteration and mineralization processes are of such a nature that they create favorable conditions for block caving methods, both in the ore and the capping rocks. Close fracturing is a universal characteristic in this type of deposit and also in the asbestos, iron, and limestone mines studied.

Summary of Geologic Factors

Numerous basic facts in 54 different cases that were studied concerning the relation of geological data to mining methods may be summarized under three general headings: 1—planes of weakness. 2—effects of mineralization, 3—other characteristics.

Planes of Weakness

1—Open stopes with pillars are generally used in deposits notable for their simplicity of structure, absence of extensive faulting and alteration, and competency of rocks and ore at relatively shallow depths.

2—Bedding planes may or may not be important causes of rock failure or weakness, depending upon their spacing, nature of partings, and type of rock.

3—Complexity of structure may or may not contribute to weakening of ore and rocks, depending on the nature of contacts and component members.

4—Rock weakness may be caused by either pre-ore or post-ore faulting, the latter being the more common cause. Pre-ore fractures may be healed by mineralization or serve as a means of weakening by alteration or subsequent movement.

5—Schistosity, particularly in relatively fine-grained rocks, usually is not a serious source of weakness.

6—Even slight post-mineral movement may cause failure in a brittle ore complex.

7—Contacts between ore and wall rocks often form important planes of weakness.

8—Intersections of shear zones may cause prominent irregularities that create mining problems.

9—The presence of joints, faults, contacts, and bedding planes relieves stresses that would otherwise be built up in the rock.

10—Internal *gouge slips* in the ore affect its strength and consequently the method of mining.

Effects of Mineralization

1—The conversion of limestone to chert and flint in the Tri-State district strengthened the rocks.

2—At the Horne mine, Noranda, Que., and at Ducktown, Tenn., the massive sulphide ores are very strong. Microscopic studies of sulphide ore show that

Table II. Intensity Factors for Non-Caving Methods

Stoping Method	Pre-Mineral Faulting, Etc.	Post-Mineral Faulting, Etc.	Alteration	Silicification or Strengthening Mineral
Open stopes	Negligible to moderately strong	Negligible to moderately weak	Negligible to moderately weak	Negligible to moderately strong
Sublevel	Negligible to strong	Negligible to moderately weak	Negligible to moderately weak	Negligible to strong
Shrinkage	Moderately weak to strong	Negligible to moderately weak	Negligible to moderately strong	Negligible to very intense
Cut-and-fill	Moderately strong to very intense	Moderately strong to very intense	Moderately strong to very intense	Negligible to very intense
Square-set	Moderately strong to very intense	Moderately strong to very intense	Moderately strong to very intense	Negligible to very intense

even very small cracks are healed by mineralization, which contributes materially to the strength of ore.

3—Silicification and mineralization of rhyolite breccias has in many cases strengthened them sufficiently so that they will support themselves in large openings.

4—The strengthening effect of silicification apparently may in some cases more than offset the weakening effects of sericitization. A high silica content of the original rocks is often essential for silicification to take place.

5—Uniformity of grade of ore affects the choice of mining methods: uniform grades usually require simpler methods of mining.

Other Characteristics

1—Strong rocks are found among igneous, sedimentary, and metamorphic type. Shale is almost universally weak.

2—A study of the Hollinger deposit shows that a majority of the geologic events in its history had an important effect upon the final structural strength of the ore and rock.

3—Branching of orebodies usually requires the use of a selective or closely supporting method of mining.

4—At the United Verde mine the rocks are strong to weak in the following order: massive sulphide (non-ore), porphyry, and schist.

5—In some cases, for otherwise similar structural conditions, the size of veins was the determining factor in a choice between shrinkage stoping and cut-and-fill, the first being employed in wider veins.

6—Where the mineralization has tended to follow joints, planes, and fractures into the walls of replacement veins, close wall support is necessary for complete extraction and clean mining.

7—Alteration of rocks in the Butte area was influenced by temperature of the solutions, chemical composition, and concentration. Degree of alteration is apparently not entirely dependent upon the degree of crushing or fracturing of the rock.

8—The persistence or continuity of orebodies both horizontally and vertically seriously affects the method of mining. Discontinuous deposits usually require selective methods.

9—In certain cases slates and graphitic rocks may act as lubricants along slip planes and facilitate adjustments of rock pressures and stresses.

10—Hard brittle rocks are more susceptible to bursting than soft weak ones.

11—The factors influencing the incidence and severity of rockbursts are: depth of workings, structural features of ore and enclosing rocks, dip of orebody, concentration of mining operations, and rate of mining.

12—In deposits employing caving methods a weak capping is usually an important requisite. Weakness is generally due to fracturing, alteration, leaching, or the presence of inherently weak rocks.

13—Drying of mine rock by pumping or ventilation often causes certain types of rocks to slack, slough, or crumble.

14—Massive size of an ore deposit is generally, but not always, a necessary requisite to successful block caving.

15—Variation in the type of wall rock or in the degree of faulting or alteration may permit the use of different types of mining in the same deposit.

Conclusions

Of all of the causes of weak mine rock structures, post-mineral faulting and *destructive* alteration are the most important. Pre-mineral faulting usually results in the weakening of rocks and ores, but to a lesser degree than the first two causes, usually because the mineralization processes healed the fractures caused by previous dynamic movement. Both silicification and certain other types of mineralization have a strengthening effect upon rock structures. They may come about as a result of either primary or secondary processes.

There appears to be no direct correlation between genetic rock types and their tendency toward being strong or weak. Their strength is a function not only of the physical properties of the rocks themselves, but their environment and geological history as well.

An interesting comparison can be drawn between the four factors given in Table II.

As might be expected, there is considerable overlapping of the effects of the more crucial geological factors influencing strength of rock and ore. Effects of one factor may be offset by those of another. For example, silicification may create a very strong but brittle rock structure easily weakened by further dynamic movement of the rocks. This appears to be true for some of the square-set mines studied.

Application of geological data to mining methods must be combined with other scientific methods, and if the largely qualitative geological data that have been described are to be employed to best advantage, they must be used in conjunction with available quantitative data concerning stress analysis and the physical properties of rock specimens of laboratory size.

References

[1] H. E. McKinistry, geologist, Harvard University: Personal communication.

[2] C. F. Jackson and E. D. Gardner: Stoping Methods and Costs. U. S. Bur. Mines *Bull. 390* (1936).

[3] R. U. King: A Study of Geologic Structure at Climax in Relation to Mining and Block Caving. *Trans.* AIME (1946) **163**.

Characteristics of Titaniferous Concentrates

Study of Chemical and Mineralogical Composition of Beach Sands from North Carolina, Florida, Brazil, and India Leads to a Theory Concerning the Origin of Titaniferous Concentrates . . .

Since the composition and structure of the beach sand concentrates correspond so closely to what would be expected of ilmenites that have been altered by oxidation and leaching, there is no reason to postulate the existence of the hypothetical compound, arizonite, to account for the composition of titaniferous beach sand concentrates. The four concentrates studied are examples of the different products that can result from various degrees of alteration of primary ilmenite.

by L. E. Lynd, H. Sigurdson, C. H. North, and W. W. Anderson

CONSIDERABLE uncertainty is revealed in the literature regarding the nature of the titanium minerals which make up the bulk of the heavy, opaque fractions of numerous beach sand deposits of the world. An investigation was made, therefore, of beach sand concentrates of North Carolina, Florida, Brazil, and India. Magnetic concentration, X-ray, and microscope data were obtained which show that these concentrates consist essentially of ilmenite and its alteration products. The alteration, brought about by oxidation and leaching of iron values, has resulted in upgrading the ores to a range of 56 to 64 pct TiO_2, as compared with 52.7 pct in ilmenite of theoretical composition.

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Conclusions drawn regarding the nature of the dominant titanium-bearing mineral in beach sand deposits have been based mainly on chemical composition, specific gravity, and petrography. This material has usually been referred to as ilmenite or weathered ilmenite. It has also been referred to as *arizonite* because in chemical composition it resembles an occurrence in Arizona which was described by Palmer[1] in 1909.

The chemical composition of Palmer's arizonite corresponded closely to the formula $Fe_2O_3 \cdot 3TiO_2$. From approximate measurements of crystal angles on a large imperfect crystal with rounded faces, the

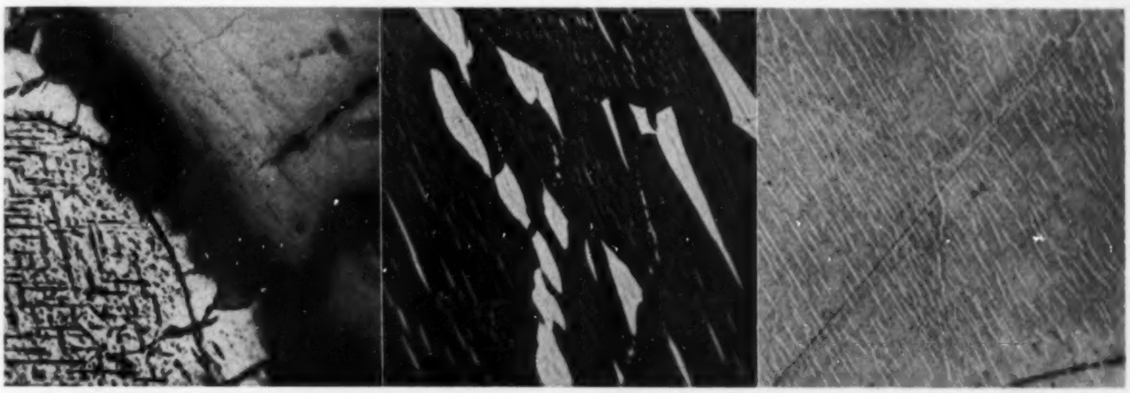


Fig. 1 (left)—MacIntyre rod mill feed showing coarse homogeneous ilmenite and coarse magnetite containing intergrown ilmenite. Gangue minerals rim ilmenite bodies in magnetite and often fill intergranular space. X700. Fig. 2 (center)—Ore from Baie St. Paul showing oriented exsolution lenses of hematite (light) in coarse ilmenite (dark). Dark streaks within the hematite are exsolution bodies of ilmenite. X700. Fig. 3 (right)—Skondal ore, showing very fine exsolution lenses of hematite (light gray) in ilmenite (dark gray). X700.

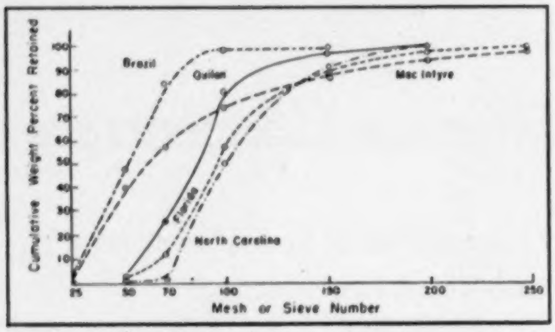


Fig. 4—Results of sieve analysis of ores.

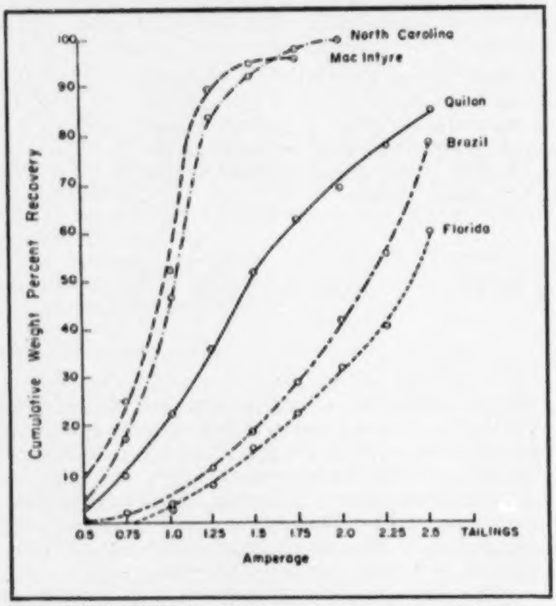


Fig. 5—Cumulative weight percent of ores concentrated at various amperages.

Fig. 6—TiO_2 contents of ore fractions concentrated at various amperages.

crystal form was thought to be monoclinic, not corresponding to any mineral then known. However, the possibility of another symmetry was admitted, and in 1944 Ernst[2] showed that considering the accuracy of measurement the symmetry can be interpreted with equal justification as rhombohedral, corresponding to that of hematite. After making studies by X-rays and polished sections, Ernst concluded that arizonite is an example of extensive replacement of specular hematite by rutile.

In 1950 Overholt, Vaux, and Rodda[3] concluded on a basis of X-ray measurement that arizonite is weathered ilmenite. They also pointed out that with vertical polarized light alteration of ilmenite can be observed microscopically in polished sections.

Attempts by Pesce[4] and later by Ernst[2] to synthesize a compound $Fe_2O_3 \cdot 3TiO_2$ were unsuccessful. With mixtures of this composition Ernst obtained only pseudobrookite ($Fe_2O_3 \cdot TiO_2$) and small amounts of rutile, indicating extensive solid solution of TiO_2 in pseudobrookite.

Although evidence is lacking for the existence of a compound $Fe_2O_3 \cdot 3TiO_2$, the name *arizonite* has been mentioned frequently as applicable to large beach sand deposits of titanium minerals.

In 1945 Miller[5] stated that the so-called ilmenite of Travancore is arizonite. In 1949 Thoenen and Warne[6] listed arizonite as a minor constituent of ilmenite-bearing beach sands. Gillson[7,8] applied the name to the ilmenite deposits of Florida; Travancore, India; and some parts of Brazil, stating, however, that the mineral had not been proved to be truly arizonite.

A number of investigators who have studied Florida sands have favored the view that the material in question is actually weathered ilmenite. On X-ray examination of Florida ore in 1945, Miller[5] found weak lines of ilmenite and concluded that the ore was unlike the type of arizonite from Arizona. In 1948 Creitz and McVay[9] and Spencer,[10] using X-ray and other evidence, concluded that the heavy opaque minerals from Florida sands are leucoxenes having variable TiO_2 contents and that they may have formed by weathering of the ilmenite originally present in the deposit.

Cannon[11] (1950) believed: 1—that the Florida deposits are altered ilmenites, 2—that the loss of iron takes place molecule by molecule throughout the series from true ilmenite to pure leucoxene, and 3—that pure leucoxene is a mass of microfine rutile crystals. No X-ray data on Quilon or Brazil sands were found in the literature.

No systematic investigation of polished sections of *ilmenite* sands in reflected light has been described so far, and no micrographs have been presented to give evidence of structure. Creitz and McVay[9] examined polished sections but stated that these did not provide useful information.

Review of Ilmenite Mineralogical Compositions

To provide a suitable background against which titaniferous beach sands can be considered, a few typical associations of ilmenite in various rock deposits are described below.

By far the greater number of ilmenite rock deposits in the world are intimately associated with iron oxide that may be present as hematite or magnetite. Depending on conditions during crystallization, the ilmenite and iron oxides may form coarsely granular aggregates, fine intergrowths, or solid solutions.

Table I. Screen Analyses of Head Samples of Ores, Cumulative Weight Percent Retained

Sieve No.	Sieve Opening, In.	MacIntyre Ilmenite	Brazilian Sand	North Carolina Sand	Quilon Sand	Florida Sand
25	0.028	0.7	2.2	0.0	0.0	0.0
50	0.0117	39.2	48.8	0.75	2.2	2.0
70	0.078	57.2	84.0	1.5	26.4	11.0
100	0.0055	74.5	98.5	51.0	81.3	58.0
150	0.0041	85.5	100.0	92.0	96.8	89.0
200	0.0029	94.5		100.0	99.0	98.0
250	0.0024	97.5			99.5	99.5
325	0.0017	98.5			100.0	100.0
Ore grain characteristics		Angular	Partially rounded	Well rounded	Well rounded	Well rounded

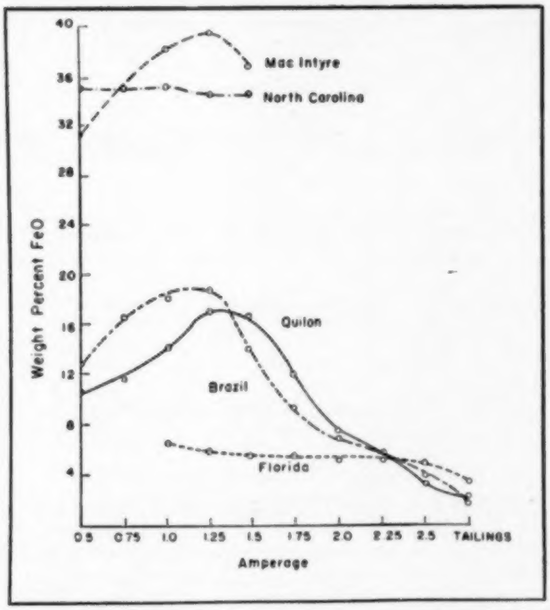


Fig. 7—FeO contents of ore fractions concentrated at various amperages.

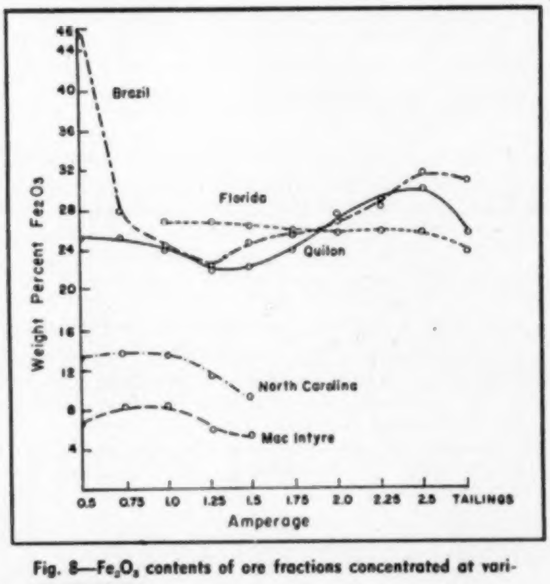


Fig. 8—Fe_2O_3 contents of ore fractions concentrated at various amperages.

In the MacIntyre orebody at Tahawus, N. Y., ilmenite and magnetite are granular. While the ilmenite fraction is free from visible magnetite at X1350, the magnetite contains lamellae of ilmenite. This is illustrated in Fig. 1.

In the deposits at Baie St. Paul and Allard Lake, Quebec, hematite is present as elongated lenses in parallel orientation in the ilmenite matrix, see Fig. 2. In the orebody at Skondal, Norway, hematite is present as uniformly disseminated fine lenses in the ilmenite matrix, Fig. 3.

On examination of polished sections in reflected light with a Bausch and Lomb research metallograph the characteristic structural features of each of the above unaltered ore types are readily discernible. The presence of similar textural features in grains from beach sand deposits suggests that primary ilmenite was the source of the deposits.

Microscopic and X-ray examination of ilmenites in this laboratory during the period 1947 through

Table II. Chemical Composition of Various Ilmenite Concentrates

Type of Ore	TiO_2, Pct	FeO, Pct	Fe_2O_3, Pct	Other
MacIntyre	44.6	36.2	6.9	12.3
North Carolina	49.0	33.9	12.2	4.9
Quilon	58.2	10.2	24.3	7.3
Brazil	56.1	7.0	27.7	9.2
Florida	64.1	4.7	25.6	5.6
Theoretical ilmenite	52.7	47.3		

1950 had given specific evidence of variations in structural and mineralogical compositions from ore to ore and within individual ores. In the case of beach sands the variations were apparently caused by different degrees of alteration of each ore and of its individual grains.

To study these variations more effectively and to correlate the degree of alteration with other features such as chemical and mineralogical composition, it was considered advisable to separate each ore into fractions which would show varying degrees of alteration. Magnetic concentration was selected as the most effective way of achieving such a separation. Evidence of wide variations in the composition of different magnetic fractions of beach sand ilmenites from Senegal, Travancore, and Florida had been observed previously by members of this organization.

Description of Ores

The ores selected for investigation differed markedly in their degree of alteration. North Carolina beach sand was only slightly altered, while sands of Quilon, India; Guarapari, Brazil; and Trail Ridge, Fla. showed increasing degrees of alteration. The Florida ore fraction used was that designated as the magnetic concentrate and did not include the most highly weathered portion of the ore, usually referred to as leucoxene, which is grayish white in color, insoluble in acid, and 80 to 90 pct TiO_2. MacIntyre ilmenite was selected as a standard unaltered ilmenite because of its virtual freedom from iron oxide intergrowths.

Ores selected for testing differed in particle shape. Ore grains from New York State were highly angular, grains from Brazil angular but partially rounded, and grains from Florida, North Carolina, and Quilon well rounded.

Screen analyses, Table I and Fig. 4, on representative head samples of these ores show that all were

Table III. Concentration, Chemical, and Mineralogical Data on Concentrates of Various Titaniferous Ores

Amp.	Prod. Dist., Wt Pct	Analyses-Weight, Pct				Recovery						Weight Ratio		Mineralogical Composition, Total Ore Fraction, Pct		
						TiO_2		FeO		Fe_2O_3		Fe(Total) / TiO_2	Fe^{3+} / Fe(Total)			
		TiO_2	FeO	Fe_2O_3	Others (Gangue)	Wt	Wt Pct	Wt	Wt Pct	Wt	Wt Pct			Fresh Ilmenite	Altered Ilmenite	Others
MacIntyre																
0.5	9.5	36.2	31.5	6.9	25.4	3.4	7.6	3.0	8.3	0.6	8.7	0.81	0.17	95+	0	<5 magnetite
0.75	13.5	44.0	35.0	8.3	12.7	6.8	15.3	5.4	14.9	1.3	18.8	0.75	0.18	95+	0	Trace magnetite
1.0	27.3	48.4	38.3	8.4	4.9	13.2	29.6	10.5	29.0	2.3	33.3	0.74	0.17	100	0	
1.25	37.3	49.6	39.6	5.4	5.4	18.5	41.5	14.8	40.9	2.0	29.0	0.70	0.11	100	0	
1.50	5.2	45.9	36.8	4.7	12.6	2.4	5.4	1.9	5.3	0.2	2.9	0.70	0.10	100	0	
1.75	0.9	19.9	22.7	8.9	48.5	0.2	0.4	0.2	0.5	0.1	1.5	1.2	0.26	100	0	
Tailing	4.3	2.2	10.6	9.3	77.9	0.1	0.2	0.4	1.1	0.4	5.8	6.7	0.44			
Total	100.0					44.6	100.0	36.2	100.0	6.9	100.0					
North Carolina																
0.5	5.0	49.0	35.1	13.0	2.9	2.4	4.9	1.7	5.0	0.6	4.9	0.74	0.25	90	5	5 magnetite
0.75	12.0	49.5	35.1	13.3	2.1	5.9	12.0	4.2	12.4	1.6	13.1	0.74	0.25	95	<5	Trace magnetite
1.0	30.0	49.4	35.5	13.1	2.0	14.8	30.2	10.6	31.3	3.9	32.0	0.74	0.25	90	5	5 magnetite
1.25	36.7	50.8	34.5	11.4	3.3	18.6	38.0	12.7	37.5	4.2	34.4	0.69	0.23	90	5	5 magnetite
1.50	8.3	51.3	34.4	8.9	5.4	4.3	8.8	2.8	8.5	0.7	5.7	0.64	0.19	90	8	2 magnetite
1.75	5.9	42.9	24.7	14.6	17.8	2.5	5.1	1.5	4.4	0.9	7.4	0.68	0.35	80 to 85	15	<5 magnetite
2.0	2.1	22.4	12.8	13.0	51.8	0.5	1.0	0.3	0.9	0.3	2.5	0.85	0.48	20	80	
Total	100.0					49.0	100.0	33.9	100.0	12.2	100.0					
Quilon																
0.5	2.9	60.5	10.9	25.3	3.3	1.8	3.1	0.3	2.9	0.7	2.8	0.43	0.68	20	80	
0.75	6.5	59.5	11.7	25.3	3.5	3.9	6.7	0.7	6.9	1.6	6.4	0.45	0.66	25	75	
1.0	12.3	59.1	13.5	24.2	3.2	7.3	12.6	1.7	16.7	3.0	12.1	0.46	0.62	30	70	
1.25	13.1	58.3	17.1	21.5	3.1	7.6	13.1	2.2	21.6	2.8	11.3	0.49	0.53	35	65	
1.50	15.5	58.7	16.3	21.7	3.3	9.1	15.6	2.5	24.5	3.4	13.7	0.47	0.54	35	65	
1.75	10.1	59.7	12.1	24.2	4.0	6.0	10.3	1.2	11.8	2.4	9.7	0.44	0.66	20	80	
2.0	8.3	60.1	7.8	27.2	4.9	5.0	8.6	0.6	5.9	2.3	9.3	0.42	0.76	10	90	
2.25	7.9	60.8	5.6	28.8	4.8	4.8	8.2	0.4	3.9	2.3	9.3	0.40	0.82	5	95	
2.5	7.0	60.7	4.1	29.5	5.7	4.2	7.2	0.3	2.9	2.1	8.5	0.39	0.86	2	98	
Tailing	16.4	52.0	2.2	25.7	20.1	8.5	14.6	0.3	2.9	4.2	16.9	0.38	0.91	0	100	
Total	100.0					58.2	100.0	10.2	100.0	24.3	100.0					
Brazil																
0.5	0.5	30.4	12.6	45.5	5.5	0.2	0.3	0.1	1.4	0.2	0.7	1.1	0.71	30	50	20 magnetite
0.75	0.9	52.4	16.3	28.0	3.3	0.5	0.9	0.1	1.4	0.2	0.7	0.62	0.61	40	60	Trace magnetite
1.0	2.4	54.0	17.9	24.3	3.8	1.3	2.3	0.4	5.7	0.6	2.1	0.57	0.55	50	50	Trace magnetite
1.25	7.5	54.6	18.6	21.7	5.1	4.1	7.3	1.4	20.0	1.6	5.8	0.54	0.51	40	60	
1.50	7.6	55.6	13.4	24.6	6.4	4.2	7.5	1.0	14.3	1.9	6.9	0.50	0.62	25	75	
1.75	10.1	55.3	9.2	26.2	9.3	5.6	9.9	0.9	12.9	2.6	9.4	0.46	0.72	15	85	
2.0	12.3	53.3	7.4	26.9	12.4	6.6	11.8	0.9	12.9	3.3	11.9	0.46	0.77	10	90	
2.25	14.9	56.4	5.6	28.4	9.6	8.4	15.0	0.8	11.4	4.2	15.2	0.43	0.82	1	99	
2.5	22.0	59.7	3.5	30.7	6.1	13.2	23.6	0.8	11.4	6.7	24.2	0.41	0.89	0	100	
Tailing	21.8	55.1	2.9	29.4	12.6	12.0	21.4	0.6	8.6	6.4	23.1	0.41	0.90	0	100	
Total	100.0					56.1	100.0	7.0	100.0	27.0	100.0					
Florida																
1.0	3.5	61.4	6.5	27.0	5.1	2.1	3.3	0.2	4.3	0.9	3.5	0.39	0.77	5	95	
1.25	4.7	62.6	5.6	27.0	4.8	2.9	4.5	0.3	6.4	1.3	5.1	0.37	0.81	2	98	
1.50	6.9	63.0	5.5	26.6	4.9	4.3	6.7	0.4	8.5	1.8	7.0	0.36	0.81	2	98	
1.75	7.7	63.0	5.4	26.4	5.2	4.8	7.5	0.4	8.5	2.0	7.8	0.36	0.82	2	98	
2.0	8.5	63.4	5.1	26.3	5.2	5.4	8.4	0.4	8.5	2.2	8.6	0.35	0.82	1	99	
2.25	9.3	63.2	5.3	26.6	4.9	5.9	9.2	0.5	10.6	2.5	9.8	0.36	0.82	0	100	
2.5	19.3	63.1	5.0	26.3	5.6	12.2	19.0	1.0	21.3	5.1	19.9	0.35	0.82	0	100	
Tailing	40.1	66.1	3.8	24.4	5.7	26.5	41.4	1.5	31.9	9.8	38.3	0.30	0.85	0	100	
Total	100.0					64.1	100.0	4.7	100.0	25.6	100.0					
Theoretical ilmenite		52.7	47.3									0.70	0.00			

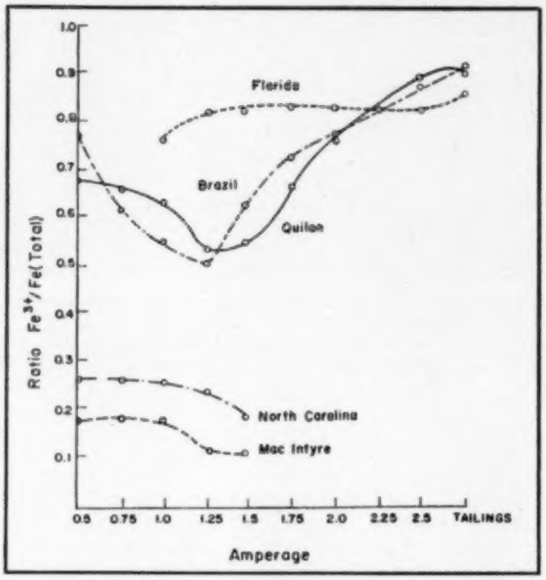


Fig. 9—Ratio $Fe^{3+}/Fe(total)$, indicating relative degree of oxidation in ore fractions concentrated at various amperages.

essentially finer than 25 mesh and 85 to 100 pct were retained on 150 mesh. Chemical analyses of the ores, presented in Table II, show that the TiO_2 contents ranged from 44.6 to 64.1 pct, the FeO from 4.7 to 36.2 pct, and the Fe_2O_3 from 6.9 to 28.2 pct.

Methods and Results of Investigation

Magnetic Concentration: The ores were separated into fractions in order of decreasing magnetic susceptibility by a Stearns ring type *D* magnetic separator, No. 0, a two-pole machine rated at 28,000 ampere-turns and 440 maximum wattage. The separator was operated at 110 v in conjunction with a rheostat which allowed variation of the current from 0.5 to 2.5 amp. The maximum air-gap setting of 3/16 in. was maintained throughout the tests. A Syntron vibratory feeder machine, Model FM-0-10, provided a satisfactory means of feed control.

A representative sample of each ore was separated into several fractions by the following method:

1—An initial concentrate was recovered at the minimum setting of 0.5 amp.

2—The tailings fraction from this step was reprocessed to yield a concentrate at 0.75 amp.

3—This procedure was repeated at successively higher amperages, as indicated in Table III, until all the ore was concentrated or the maximum amperage of 2.5 was reached. The weight percent distributions of the fractions obtained from each ore at the various amperages are presented in Table III and Fig. 5.

Differences in magnetic susceptibility of the various ores were pronounced. MacIntyre and North Carolina, although differing considerably in particle size range and shape, were almost identical in magnetic behavior. Both ores required only 1.5 to 1.75 amp for recovery of practically all the titanium values in the concentrates, whereas with ore from Quilon and Brazil, and especially with ore from Florida, considerable percentages of the titanium values remained in the tailings from the 2.5-amp concentration. Although ores from Brazil and Florida differed considerably in particle size and shape their magnetic behavior was similar. Quilon ore resembled Florida ore with respect to particle size but was considerably more magnetic. It was therefore apparent that particle size differences between the ores did not affect significantly their magnetic behavior or the distribution of the ore concentrates.

No doubt further separation of the 2.5-amp tailings from ores of Quilon, Brazil, and Florida could be achieved readily by the use of higher intensity separation equipment.

Chemical Analysis: Each of the products obtained from the magnetic concentrator was analyzed for TiO_2, FeO, and Fe_2O_3 by standard analytical procedures. Results of these analyses, indications of the amount of gangue constituents present in each fraction, and weight and weight percent distributions of TiO_2, FeO, and Fe_2O_3 are listed in Table III. The chemical data are also expressed graphically in Figs.

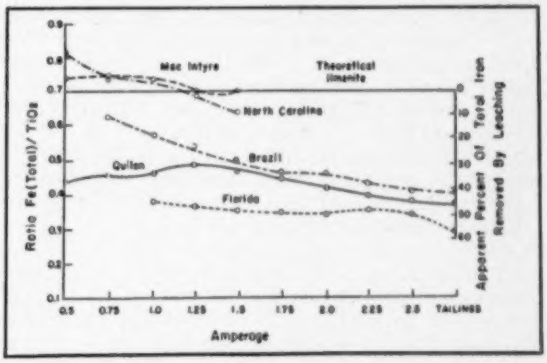


Fig. 10—Ratio $Fe(total)/TiO_2$, indicating relative degree of leaching of iron oxides from ore fractions concentrated at various amperages.

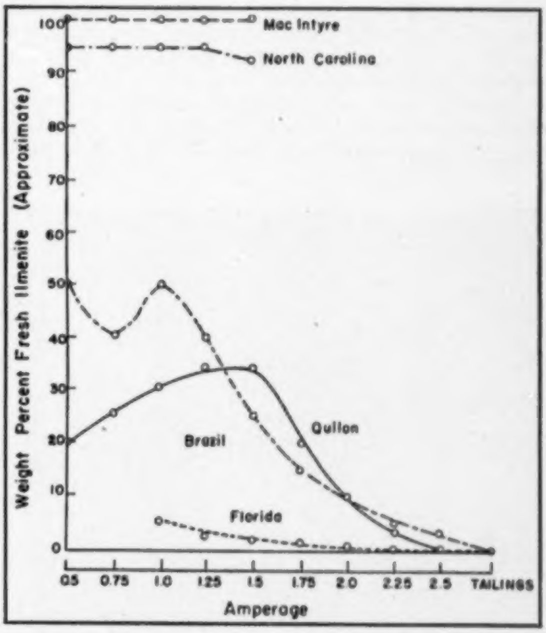
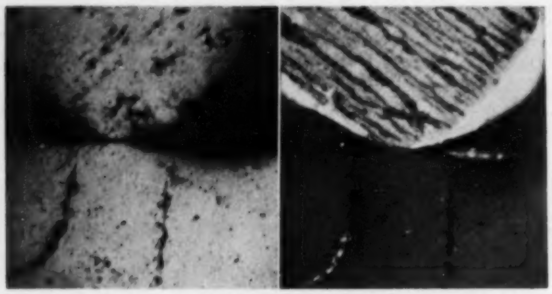


Fig. 11—Fresh ilmenite contents of ore fractions concentrated at various amperages.



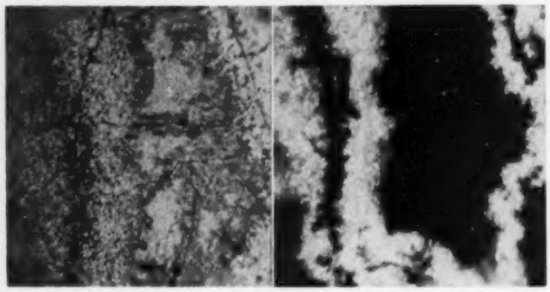


Fig. 12 (left)—Brazilian ore grains, altered to different degrees, in bright light (left) and in polarized light (right). More highly altered areas are brighter in polarized light than are less altered areas. Originally X250; reduced one-half. Fig. 14 (right)—Highly altered grain of Quilon ore, in bright light (left) and in polarized light (right). The most highly altered portions are finely granular, porous, and bright in polarized light. Alteration appears to have proceeded most rapidly along fractures. Originally X1000; reduced one-half.

6, 7, and 8. Some of the values plotted for tailings fractions are erratic because of high gangue content.

Calculated ratios of Fe^{2+}/Fe(total) for each fraction are presented in Table III and Fig. 9. These ratios range in general from 0.10 to 0.25 for MacIntyre and North Carolina ores, from 0.53 to 0.91 for Quilon and Brazilian ores, and from 0.77 to 0.85 for ore from Florida, in contrast to a ratio of 0.0 in theoretical ilmenite. The values give an indication of the degree of oxidation of the different fractions and vary considerably from ore to ore.

Calculated ratios of Fe(total)/TiO_2 for each fraction range in general from 0.64 to 0.81 for MacIntyre and North Carolina ores and from 0.30 to 0.62 for ores of Quilon, Brazil, and Florida, compared to a ratio of 0.70 for theoretical ilmenite. These values, which are shown in Table III and Fig. 10, give an indication of the degree of leaching of iron from the various fractions.

Microscopic Examination: A sample of each fraction of the various ores was mounted in plastic, and polished sections were prepared by grinding with coarse and fine carborundum on a cast iron lap, followed by polishing on billiard cloth with a slurry of Linde A alumina. Buehler laboratory polishing equipment was used.

The polished sections were examined with a Bausch and Lomb research metallograph at high magnification (X1350). It was found that lower magnifications did not bring out distinctly the differences in color between fresh ilmenite and slightly altered ilmenite. The use of a high-power oil immersion objective, however, brought out color differences in good contrast, both in bright and polarized light, so that fresh ilmenite could be distinguished readily from even slightly altered material. Since it was considered of particular interest to note the relative amounts of fresh ilmenite in the various fractions, estimates of these amounts are included in Table III under mineralogical composition and are presented graphically in Fig. 11. These estimates are considerably lower than the percentage of grains containing fresh ilmenite, since the amount of fresh ilmenite in the various grains ranged from 0 to 100 pct. The overall fresh ilmenite contents of the head samples of ore amounted to 100 pct for MacIntyre, 90 pct for North Carolina, 20 pct for Quilon, 10 pct for Brazil, and 1 pct for Florida.

Fig. 13—Quilon ore grain, partially altered, with fresh ilmenite core (dark gray), surrounded by light gray granular alteration products. X1000.

The material designated as fresh ilmenite was brown to pinkish brown in bright light in contrast to the grayish-white, minutely granular, porous appearance of the altered portions. The fresh ilmenite was present both as discrete grains and as skeletal remnants in partially altered grains. Frequently the fresh homogeneous ilmenite graded into gray altered material.

The appearance of the altered ilmenite varied, depending on the degree of alteration. Some grains appearing grayish white and granular in bright light were dark in polarized light, as was fresh ilmenite. Other grains showed dark brown to bright yellow reflections in polarized light, in a wide variety of patterns: light and dark alternating bands, mottled areas, diffuse brown grains of various tones, or rims of light alteration products around a core of fresh or less altered material. The micrographs of polished sections of typical altered grains are shown here, see Figs. 12-16.

X-ray Diffraction: Powder X-ray diffraction patterns were obtained for selected ore fractions with a Philips high-angle Geiger-counter spectrometer with Zr-filtered Mo radiation. Samples were ground to well below 200 mesh and packed dry into an aluminum specimen holder so that a plane rectangular area was presented to the X-ray beam. The geometry of the spectrometer was set for optimum resolution and intensity of response. Patterns were recorded at a scanning rate of ¼° per min over an angular range corresponding to d-spacings from about 1.00 to 4.00 A.

Table IV lists the mineral components identified in selected ore fractions. Patterns were compared directly with those of cryptocrystalline hematite, rutile from Florida, and MacIntyre ilmenite which in turn corresponded to ASTM card index data within the limit of experimental errors.

Table IV. A Summary of Mineral Composition of Magnetic Concentrates Based on X-Ray Pattern Intensities, Interpreted from Data Provided by Chemistry, the Microscope, and the Electron Microscope

Description of Sample	Relative Amounts of Constituents*			
	Ilmenite	Hematite	Rutile	Unidentified
North Carolina ore				
1.25 amp concentrate	Very high	Trace	Absent	Absent
Quilon ore				
0.5	Major	Low	Low	Absent
1.25	Major	Minor	Absent	Absent
2.0	Minor	Minor	Minor	Trace
2.5	Low	Low	Major	Trace
Brazil ore				
1.0	Major	Low	Low	Absent
2.25	Low	Low	Minor	Trace
Florida ore				
1.0	Minor	Low	Major	Trace
2.5	Low	Low	Major	Trace

* Very high: accounts for nearly all of pattern strength.
* Major: accounts for 50 to 75 pct of pattern strength.
* Minor: accounts for 25 to 40 pct of pattern strength.
* Low: accounts for 10 to 20 pct of pattern strength.
* Trace: accounts for <10 pct of pattern strength.

Ore from North Carolina gave a strong pattern, indistinguishable from that of MacIntyre ilmenite. The other three beach sand ores (from Quilon, Brazil, and Florida) appeared mutually similar but with decreasing amounts of all crystalline components. The more highly magnetic fractions from Quilon and Brazil contained substantial amounts of normal ilmenite, but the more altered fractions appeared to contain more rutile and hematite with only negligible amounts of ilmenite. Both fractions of ore from Florida which were tested contained a small amount of ilmenite and a predominance of fine-crystallite rutile and hematite. It was almost impossible, from X-ray patterns alone, to distinguish whether the highly altered ore fractions were predominantly rutile or hematite. The patterns of the least magnetic ore fractions in this investigation often failed to contain any lines at 2.68 or 3.25 A, normally listed as the principal d-spacings of hematite and rutile respectively, but they exhibited broad weak maxima at d = 1.69 A and other spacings common to both. Therefore other factors, such as chemical composition, had to be considered in the interpretation of these patterns.

In determining crystallite diameters by X-ray diffraction it is customary to grind quartz or some other nominally pure mineral as fine as possible by mechanical means. Such a powder, assigned a crystallite size >1000 A., provides an *instrument width* or practical minimum diffraction line breadth. For the same instrument geometry, crystallites smaller than 1000 A. in diam exhibit weaker and broader lines than the standard pattern, in accordance with well-established formulae.[12,13] The smallest diameter that can be estimated in this way depends on the efficiency with which a broad line can be detected and on the crystallographic nature of the particular reflection plane. A practical minimum diameter might be about 50 A.

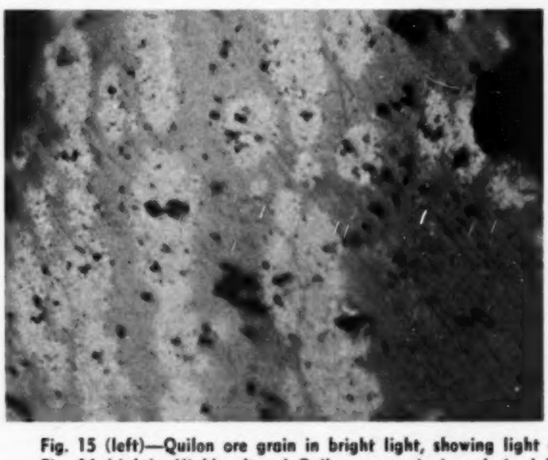
Table V lists peak intensities above background for several compounds tested under standard conditions of maximum response. Although not as rigorous a criterion as line breadth, intensity shows a regular progression downward as rutile or anatase TiO_2 crystallites decrease in size. A similar decrease in intensity is observed when two ores with relatively large crystallites are compared to a rouge hematite specimen.

Table V. Peak Intensity of Standard Patterns

Compound	Main Peak, d/n, A.	Intensity, Counts Per Sec
Rutile, sintered pigment*	3.25	138
Rutile, medium crystallite**	3.25	110
Anatase, fine crystallite†	3.54	42
Ilmenite, MacIntyre	2.75	100
Magnetite, MacIntyre	2.53	100
Hematite (polishing rouge)	2.68	50

* Diameter of (110) plane >1000 A.
** Diameter of (110) plane approximately 154 A.
† Diameter of (110) plane approximately 79 A.

When ore fractions from Quilon, Brazil, and Florida were run under the above conditions, their strongest pattern lines failed to equal the intensity of either the fine crystallite hematite or anatase, indicating that the predominant minerals in these ores approached a size range amorphous to X-rays, that is, crystallite diameters in the order of 50 to 100 A.



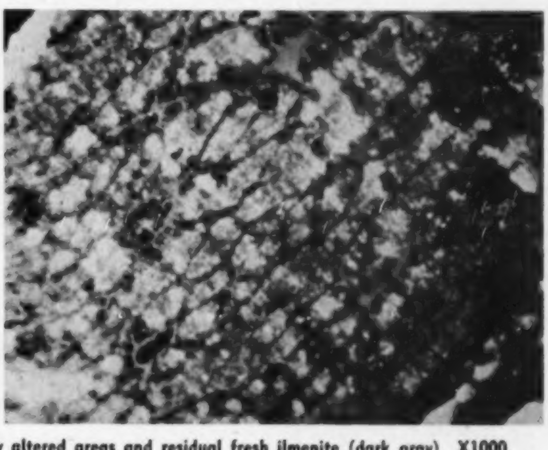


Fig. 15 (left)—Quilon ore grain in bright light, showing light gray altered areas and residual fresh ilmenite (dark gray). X1000.
Fig. 16 (right)—Highly altered Quilon ore grain in polarized light. Less altered material forms a network of gray stringers in highly altered material (light gray to white). X1000.

The factor of crystallite size helps to justify the apparent quantitative discrepancy between X-ray and microscopic estimates of ilmenite content in the ore fractions listed in Tables III and IV. X-ray estimates were based on the total pattern intensity of the detectable crystalline material rather than percent by weight of sample. Thus comparatively large crystallites of ilmenite in a few aggregates might indicate relatively high ilmenite content, whereas ultra-fine crystallites of alteration products in the remaining aggregates would go undetected.

A powdered specimen of arizonite obtained in 1946 from a small piece originating at Hockberry, Ariz., yielded a good pattern for a mixture of approximately 40 pct hematite, 40 pct anatase, and 20 pct finely crystalline rutile. This analysis agrees with the pattern described by Overholt, Vaux, and Rodda[3] and with the observations of Ernst.[2] Microscopic examination of this material revealed the presence of small hematite lenses in a matrix which was very similar in appearance to weathered ilmenite.

Electron Microscope Studies

Electron Diffraction: Patterns and micrographs were obtained of the 2.5-amp concentrate from the Florida ore and of three magnetic fractions of a less weathered Florida ore. Diffraction patterns of all samples indicated that rutile made up the bulk of the fine crystalline material present, ranging in basic particle size from about 50 to 1200A. The electron micrographs indicated that the aggregates were larger (0.1 to 1.5 microns) in the fractions of the less weathered ore than in the more weathered sample (0.005 to 0.8 microns).

Summary

The four beach sands investigated, although similar in general appearance and mode of occurrence, show considerable variation in composition and structure. The ore from North Carolina consists essentially of ilmenite, with minor amounts of intergrown magnetite, and is only slightly altered. In structure, composition, and magnetic behavior it is very similar to MacIntyre ilmenite occurring in Adirondack anorthosite and gabbro.

Examinations made by microscope, X-ray, and electron microscope of the various magnetic fractions obtained from the beach sands of Quilon, Brazil, and Florida show that ilmenite is present in various amounts in several fractions of each ore and that nearly all the non-ilmenite portion of the ores consists of a porous mixture of fine-grained rutile and iron oxide which formed as a result of alteration of the ilmenite.

Results of magnetic concentration tests emphasize the heterogeneous nature of the ores from Quilon, Brazil, and Florida. Over 90 pct of the MacIntyre and North Carolina ilmenite was recovered over a narrow amperage range on the magnetic separator, whereas ores from Quilon, Brazil, and Florida were recovered over a much wider and higher range.

The ores may be listed in order of increasing degree of alteration, and decreasing magnetic susceptibility, as follows: MacIntyre, North Carolina, Quilon, Brazil, Florida. Although more weathered than ore from Quilon, ore from Brazil is lower in TiO_2, since less of its ferric oxide has been removed by leaching, or since it contains highly weathered brown magnetite grains that are difficult to distinguish from brownish weathered ilmenite grains. Quilon, Brazil, and Florida concentrates all contain ore grains ranging in composition from fresh ilmenite to a highly altered product approaching pure TiO_2 in composition. The more magnetic fractions of ores from Quilon and Brazil contain considerable amounts of unaltered ilmenite.

Florida ore, which is higher in TiO_2 content than the other ores, shows almost complete breakdown of the original ilmenite structure, its most magnetic fraction containing only about 5 pct of fresh ilmenite. Other samples of Florida ore have been encountered which exhibit a degree of alteration intermediate between that of the Florida ore studied and Quilon ore.

The ratios of Fe_2O_3 to total iron in the different ores indicate that oxidation has accompanied alteration. The higher TiO_2 to Fe ratio in the altered ores is good evidence that leaching of iron has occurred.

Since the composition and structure of the beach sand concentrates correspond so closely to what would be expected of ilmenites that have been altered by oxidation and leaching, there is no reason to postulate the existence of the hypothetical compound, arizonite, to account for the composition of titaniferous beach sand concentrates. The four concentrates studied are examples of the different products that can result from various degrees of alteration of primary ilmenite.

Acknowledgment

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References

[1] Chase Palmer: Arizonite, Ferric Metatitanate. *American Journal of Science,* Ser. 4 (1909) **28**, No. 166, pp. 353-356.

[2] T. Ernst: Fusion Equilibria in the System Fe_2O_3-FeO-TiO_2 and Notes on the Minerals Arizonite and Pseudobrookite. *Ztsch. Angew. Min.* (1943) **4**, pp. 394-409.

[3] J. L. Overholt, G. Vaux, and J. L. Rodda: The Nature of "Arizonite." *American Mineralogist* (1950) **35**, pp. 117-119.

[4] B. Pesce: *Concerning the Titanates of Iron. Gazz. chim. ital.* (1931) **61**, pp. 107-111.

[5] Roswell Miller III: The Heavy Minerals of Florida Beach and Dune Sands. *American Mineralogist* (1945) **30**, pp. 65-75.

[6] J. R. Thoenen and J. D. Warne: Titanium Minerals in Central and Northeastern Florida. U. S. Bur. Mines *R.I. 4515* (1949).

[7] J. L. Gillson: Titanium. *Industrial Minerals and Rocks,* 2nd ed., Ch. 49, pp. 1042-1073. AIME, 1949.

[8] J. L. Gillson: Deposits of Heavy Minerals on the Brazilian Coast. *Mining Engineering* (June 1950) **187**, pp. 685-693.

[9] E. E. Creitz and T. N. McVay: A Study of Opaque Minerals in Trail Ridge, Fla., Dune Sands. *Mining Technology* (1948) **12**, *TP 2426.*

[10] R. V. Spencer: Titanium Minerals in Trail Ridge, Fla. U. S. Bur. Mines *R.I. 4208* (1948).

[11] H. B. Cannon: *Economic Minerals in Beach Sands of the Southeastern United States. Proceedings of the Symposium on Mineral Resources of the Southeastern U. S., 1949.* University of Tennessee Press, Knoxville, Tenn.

[12] L. Alexander and H. P. Klug: Determination of Crystallite Size with the X-Ray Spectrometer. *Journal of Applied Physics* (1950) **21**, pp. 137-142.

[13] B. E. Warren: *Journal of Applied Physics* (1941) **12**, p. 375.

Productivity in Mining Pitching Seams Of the Canadian Rockies

by H. Wilton-Clark

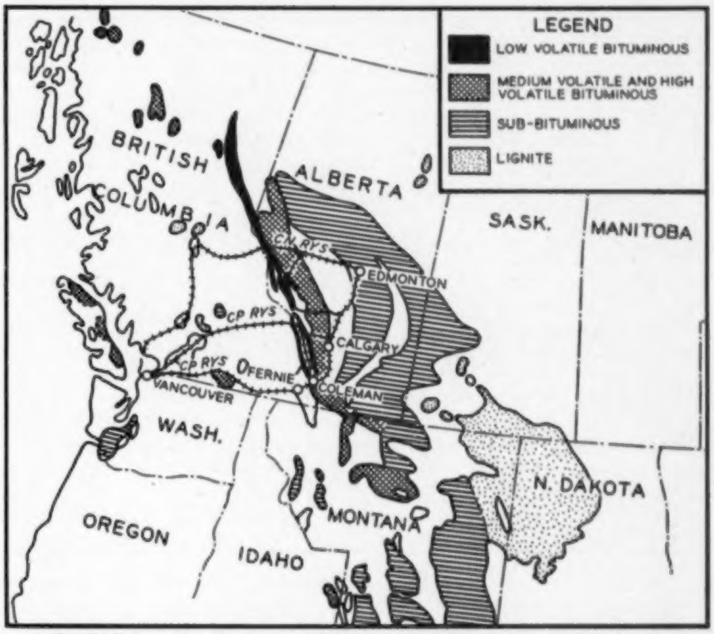

Fig. 1—Extent of coal formations in western Canada and sections of the U.S. Estimates indicate a reserve of 25,000 million tons of bituminous coal.

VARYING in thickness and in number from place to place, coal seams in the Canadian Rockies also range in pitch from nearly horizontal to vertical, sometimes with overturns. Over the entire coal-bearing area there are considerable differences of rank in coals of the same geological age, and there are marked differences in ash content and washability characteristics. Correlation of seams at mining operations within a few miles of each other has often proved impossible. These factors influence mining methods, and, of course, production results.

The oldest coal formations of western Canada are of Lower Cretaceous age, as the carboniferous sediments are marine and contain no coal. Coal is also present in formations of Upper Cretaceous and Tertiary ages. The rank of coal varies from semi-anthracite in some operations in the Kootenay and Luscar formations of the Lower Cretaceous in the Rockies to lignite in the Tertiary fields of the Saskatchewan prairies. Fig. 1 shows the general extent of the formations.

The pitching seams, chiefly Lower Cretaceous, occur in the western belt of the Rocky Mountain foothills and the eastern slopes of the Rockies themselves. (The road to Tent Mt. strip pit, elevation 7000 ft, is shown on p. 832.) Formations extend from the U. S.-Canadian boundary for several hundred miles in Alberta and continue for a similar distance in British Columbia. Present geological estimates show a probable reserve of the order of 25,000 million tons of coal ranging from high volatile bituminous to semi-anthracite, with a large percentage of coking coal, constituting one of the major world reserves of that type. It should be noted that although the quoted estimate probably errs on the conservative side, the question of access to the seams in a mountainous terrain will always be a problem; a wide divergence may exist between actual reserves and the quantities of coal economically recoverable.

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An excerpt from the Canadian government *Report of the Royal Commission on Coal 1946* states that conditions favorable to coal formation were intermittent and these intervals relatively brief in comparison with periods in which no coal was formed. Conditions were favorable to the growth or accumulation of vegetation in one area, while fresh water sediments and marine shales were being deposited in other areas. During periods of emergence the coal deposits were subjected to erosion or were covered by coarse sands and gravels from the mountains, whereas during submergence they were covered by fine clays deposited in embayments of the sea. During some of the periods of coal formation, volcanic activity deposited beds of fine volcanic ash and dust with the coal-forming vegetation.

Coal deposits reach their greatest development in the mountains and thin rapidly to the east into the plains area, where they are deeply buried beneath younger sediments. For example, in the Fernie area of southeastern British Columbia there are in places 22 seams having an aggregate thickness of 150 ft in a stratigraphic interval of 3500 ft, whereas at Coleman in the Alberta Crowsnest area the measures are only 800 ft in thickness and contain a maximum of five seams aggregating about 47 ft of coal. At Bellevue, 10 miles further east, the measures are reduced to 430 ft with only three seams aggregating about 37 ft of coal.

Subsequently the tremendous forces involved in the upthrust of the Rocky Mountains produced great displacement of the coal-bearing formations and at the same time a change in geologically young coals from low to high rank.

The floor or footwall of most seams consists of carbonaceous shales, which are almost as adaptable to bending as the coal seams themselves. The seams show very few cleats or cleavage planes and have been so weakened structurally that as mined 50 pct or more will pass through a ¼-in. screen, seldom

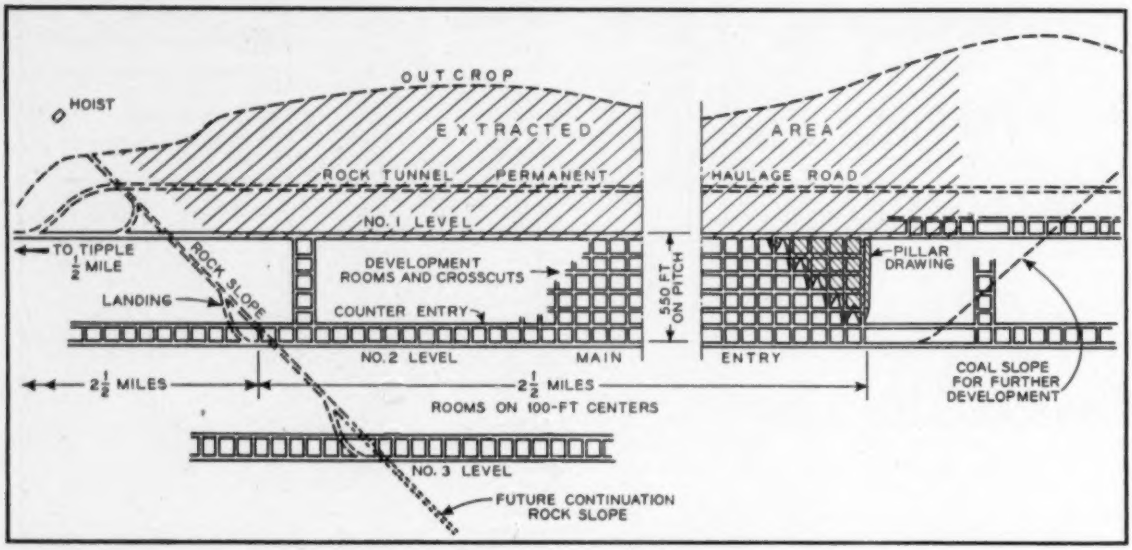

Fig. 2—A typical level in the mine shown on opposite page, Fig. 3.

more than 10 pct being larger than 6 in. Roof is usually shale, at times grading into sandstone and even conglomerate. Shale roof is usually heavy, while sandstone roof, apparently hard and sound, proves to have microscopic fault cracks (as do the shale roofs) and requires systematic timbering. Conglomerate roof is usually good.

Coal mining in the Rockies immediately followed railroad building, the chief market being for railroad fuel. The Canadian Pacific Railway crosses the mountains in two places and the Canadian National Railway in one, with two further branch lines which enter coal-bearing areas. These lines are shown in Fig. 1. The railways generally run east to west, while the coal deposits strike southeast to northwest. Where the pitching seams outcrop adjacent to a railway a mine was opened. As the railways traverse passes resulting from stream erosion the outcrops are usually accessible at valley levels. Most mines, therefore, have been started by drifts in the seams at tipple (railroad) elevation. As the valley sides rise, and the seams with them, the general custom has been to mine coal to the rise of the main entry, until the economics of haulage and travel time to and from the working faces has forced working to the dip. Fig. 2 illustrates the layout of such a mine.

In the last few years, with the advent of diesel locomotives and conversion of steam locomotives from coal to oil, coal markets have steadily declined. The loss in railway market has been taken up somewhat by use of coal in industry and by space heating. Output from the pitching seam mines for the last 14 years is shown in Table I.

The high cost of producing coal and the competition of other fuels have reduced operating mines from 15 to 9 and have forced nearly all mines to supplement their underground production with strip coal from seam outcrops. Strip coal reserves, of course, are very small compared with underground reserves in any given locality.

When coal was mined above the main entry drainage presented no difficulty because of gravity flow to the mine portal. Ventilation was also relatively easy in that airways could be vented to the outcrop when necessary. As the mines have developed dip workings, these conditions have changed. Permanent airways must be maintained for adequate ventilation, usually under conditions of deteriorating roof. The necessity for excellent ventilation is illustrated by the fact that typically the mines give off 3000 to 4000 cu ft or more of methane per ton of coal mined. The strata overlying the coal seams is usually sufficiently fractured to allow considerable water inflow, which varies in quantity in a ratio of 4 or 5 to 1 from June to December. Thus the mine shown in Fig. 2, producing 2000 tons per working day, has a minimum water inflow of 350 and a maximum inflow of 1600 imperial gallons per min, which must be gathered and pumped against 1000-ft head. This mine has two workable seams, the top seam 12 ft thick and the bottom seam varying from 4 to 8 ft. At present nearly all mining is done in the top seam. Above the main entry all coal was removed to the outcrop.

Table I. Output from Pitching Coal Seams of the Canadian Rockies, 1938 to 1952*

Year	Mines, No.	Production from Stripping, Tons	Production from Underground, Tons	Total Output, Tons
1938	15		2,792,896	2,792,896
1939	15		3,186,336	3,186,336
1940	13		3,875,910	3,875,910
1941	13		4,820,536	4,820,536
1942	13		4,981,058	4,981,058
1943	14		4,506,728	4,506,728
1944	14	116,519	4,656,516	4,773,035
1945	13	339,576	3,991,135	4,330,711
1946	13	645,413	4,330,343	4,975,756
1947	12	1,067,043	3,624,441	4,691,484
1948	13	1,611,262	3,359,405	4,970,667
1949	13	1,740,236	3,725,190	5,465,426
1950	14	1,659,898	2,982,556	4,642,454
1951	13	1,553,189	3,120,462	4,673,651
1952	9	1,335,247	3,178,870	4,514,117

* Source: Coal Statistics for Canada for years 1938 to 1952 inclusive.

Below the main entry levels are driven 550 ft apart, measured on the pitch of the seam. Each level consists of a main and counter entry, driven on 100-ft centers. These entries must naturally follow the undulations of the seam laterally, but they are driven

to a fixed grade of 0.6 pct, which allows for adequate drainage and equalizes traction required for empty and loaded trips. If a given district produces much water, a companion entry or water level is driven below the main entry, to avoid drainage ditches in the latter. Where cover is light, for example, less than 1000 ft, rooms with the necessary ventilation crosscuts can be driven as a level progresses and pillars pulled as soon as rooms are finished. As cover increases it has been found advantageous merely to drive the entries to a desirable limit and then drive rooms and pull pillars on the retreat to lessen effects of squeeze.

Fig. 3 shows sections of the entries, with a room and crosscuts. Because the coal is friable, all tight work other than a main entry is driven no more than 10 ft high, as ribs slough, leaving unsupported roof. Entries are systematically timbered with three-piece sets, with high rib and roof lagged. Rooms and pillars are taken out where possible with props and cap pieces, but otherwise with sets and lagging. Roof bolting is now being tried in entries, but so far not in rooms or pillars. It may be mentioned here that timber consumption in the operating mines varies from two to three lineal feet of timber per ton of coal extracted. Entry timbers are typically of 10-in. diam at the top, and props for rooms and pillars have 6 to 8-in. tops. When pillars are pulled the full seam is taken. Fig. 3 also indicates how rooms are driven and pillars are pulled on the retreat. Along one rib of a room a plank chute is built, 3 ft wide and 3 ft high, with the room rib forming one side. The bottom is lined with 22-gage galvanized sheet iron on which coal slides by gravity to the main entry, where it is loaded into mine cars as required. A section along a room is shown in Fig. 3. Mining is by pneumatic picks, with two miners to each room. If the coal is hard it is shot after a mining has been put in with the air picks, and in such case pneumatic rotary coal drills are used. A room 10 ft high and 10 ft wide is usually worked in two 5-ft benches, the upper bench extraction being kept ahead. When rooms and the necessary ventilation crosscuts have been completed, pillars are pulled by skipping from the top crosscut to the top of the room with as wide an area taken out as possible. This is governed by two considerations: 1—condition of roof and tendency to cave, and 2—if the roof happens to be good, by the limit angling of temporary chutes across the pitch, allowing for gravity flow of coal from the face to the point where the temporary chutes feed into the main chute in the room. At the place where the skips diverge from the room a battery of props is built across the room with only sufficient opening for a chute. When the pillar caves the cave will not extend below the battery, and rock falling down the footwall is prevented from going down the room. After such a cave, places are again driven up into the pillar blocks from below the battery, a thin chain of coal being left between the place and the cave. When the top of the pillar is again reached the new pillar split is widened by skipping until again caving occurs. The pillar is thus progressively pulled down to the main entry until only pillar stumps are left; these are usually sacrificed because of excessive squeezing. Under such methods 75 pct of the coal in a level is extracted, rising to 85 pct under good roof conditions. Usually an air hoist is installed in every tenth room, and timber, lagging, brattice, and other supplies pulled up on a sled and distributed by packing crews to adjacent places. Sometimes track and cars are installed, but there is pronounced floor heaving which generally makes the sled more practicable.

As rooms are driven up, ventilation is established by crosscuts. Brattice is carried up a room to ventilate the face until a crosscut is driven, when the lower crosscut is stopped off, usually with brattice and boards. Between the main entry of a level, which may be either intake or return air, and the counter entry acting as the opposite number, double-boarded stoppings are used, with tight slide doors for men to pass through. The chute opening is covered with several thicknesses of brattice cloth,

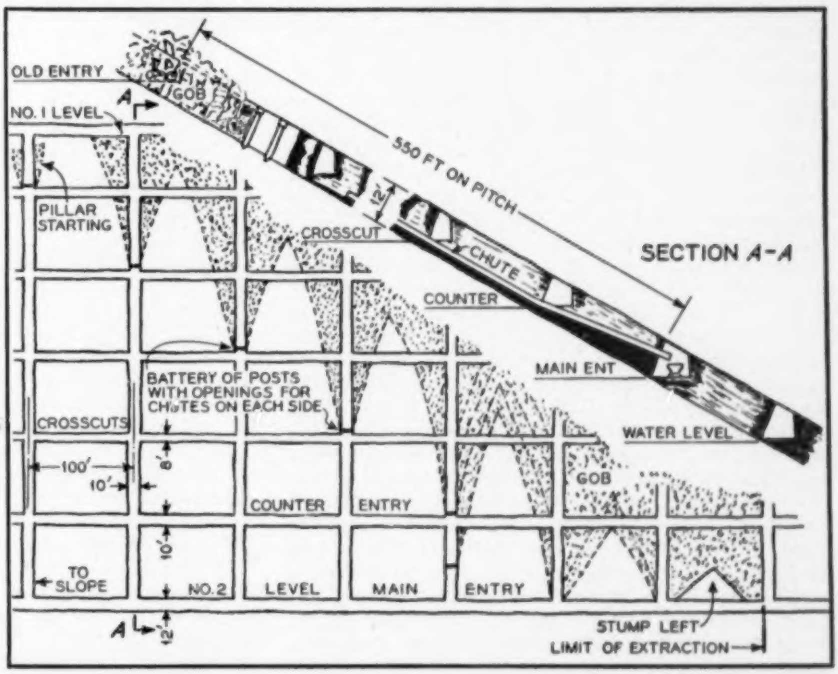

Fig. 3—Sections of entries, with room and crosscuts. Because coal is friable, all tight work other than a main entry is driven no more than 10 ft high. Entries are timbered with three-piece sets and high rib and roof are lagged. Where possible rooms and pillars are taken out with props and cap pieces.

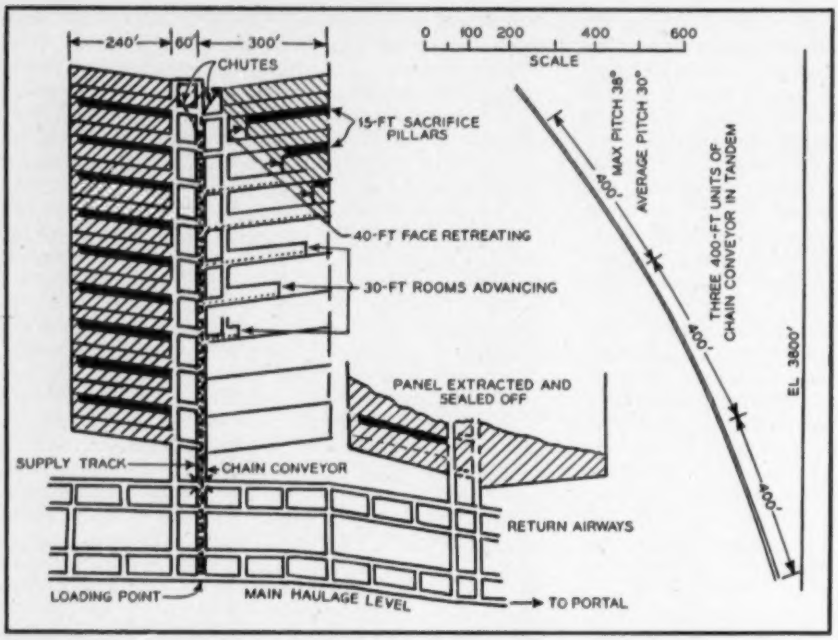

Fig. 4—The panel method for duckbill extraction. Places are driven about 1300 ft, at 60-ft centers, as shown here. Three 400-ft chain conveyors in tandem carry the coal to a loading chute at the main entry.

through which coal will pass. If the place is not abandoned because of pillar removal, this opening is boarded tight on finishing. Levels are driven from main hoisting slopes, such slopes either being driven across the pitch or in rock under the seam. The maximum desirable pitch for such slopes is 22°. At greater inclinations coal will roll off cars if the cars have been loaded level full or more.

As the initial entry is driven from a valley level into mountainous terrain, rapidly increasing cover limits working to the dip. Experience to date has shown that 2500 ft of cover is the present feasible limit. At that point workings are subject to much squeezing, and it is true to say that each entry system at that depth must be literally driven and timbered at least twice, even when a retreat system of mining is used. Also, at 2500 ft seams are subject to violent bumps, making mining at greater depths both uneconomic and extremely hazardous. To develop practical roof control at depths greater than 2500 ft, investigations have been carried on for 5 years by mining engineers, geologists, and physicists, working under the direction of the Dominion government. This is essential, as there are undoubtedly tremendous quantities of coal at great depth in the Rocky Mountains, other than the reserves mentioned earlier. However, it is too early to forecast possibilities of any solution to the depth problem.

Where a seam pitches more than 35° the system described above is still used, with the modification that rooms are angled across the pitch to allow gravity flow of coal. With this method seams can be worked up to the vertical.

Until a few years ago, where a seam was pitching less than 30°, which meant that coal would not flow in chutes, inclines 600 to 1000 ft apart were driven up the pitch. Small air-powered hoists capable of handling one to three mine cars were installed in these inclines and rooms were driven left and right on the strike of the seam. Cars were hauled from incline to face by horses. Sufficient pillar was left between rooms to allow safe mining, and pillars were drawn after rooms were driven. Coal was hand-loaded into cars. Coal from the pillar skips was pushed or bucked down sheet irons to the rooms by manpower. In some mines rooms were driven straight up the pitch as wide as roof conditions would allow, separated by minimum pillars. Rooms were double-tracked with light rail and fitted with a pulley lying on the floor, carrying about three turns of rope and fitted with a brake, so that a loaded car going down the room would pull an empty up. This device was anchored to a prop and moved up as the face progressed.

Under the method described for the mine shown in Fig. 2 production is:

Raw coal per man day overall	4.31 tons
Refuse loss at preparation plant, 11.6 pct	0.50 tons
Net production clean coal per man day	3.81 tons

Costs are divided as shown in Table II.

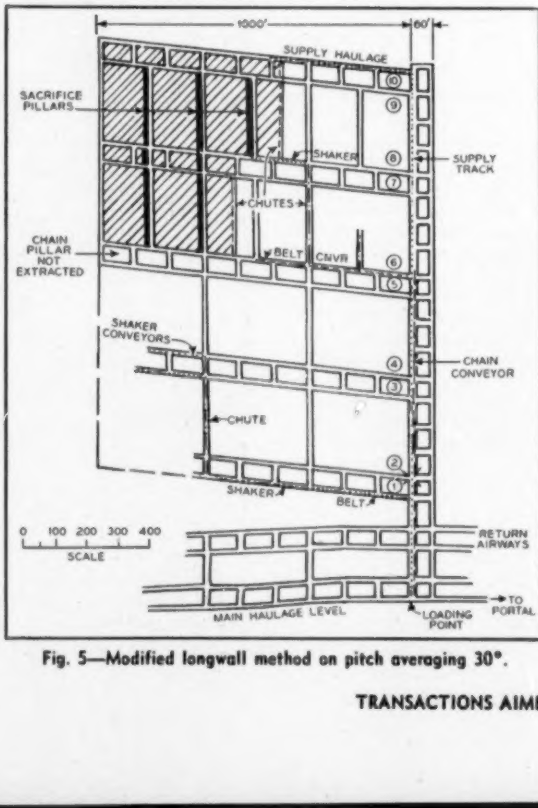

Fig. 5—Modified longwall method on pitch averaging 30°.

Table II. Costs of Mine Production from Pitching Seams by Method Shown in Fig. 2

Mining

Category	Total Shifts, Pct
Contract miners	29.344
Company miners	1.458
Timbermen	4.666
Timber packers	6.041
Rock dusting	0.401
Ventilation	0.805
Pumpmen	2.101
Pipe fitters	0.338
Handling materials	0.196
Salvage	0.106
Rock handling	0.222
Warehouse and lamphouse	1.107
Maintenance	0.053
Mine timber	0.702
Explosives	0.030
Mantrip	0.007
Tools and nails	0.010
Warehouse	0.288
Administration	0.517
Pit bosses	0.898
Firebosses	3.181
Engineers	
Electrician, timekeeper, consulting engineer, safety supervisor	0.742
Total	53.213

Category	Total Cost, Pct
Contract miners	25.380
Company miners	0.956
Timbermen	3.012
Timber packers	3.796
Special work	0.531
Miscellaneous labor	10.102
Total	43.786

Haulage

Category	Total Shifts, Pct
Locomotive drivers	5.509
Rope riders	2.585
Tuggermen	0.799
Track layers	2.465
Pipe fitters	0.123
Chute loaders	3.940
Chute repairs	0.149
Hoistmen	1.763
Sandmen	0.186
Car repairs	0.812
Oil and grease	0.437
Warehouse	0.292
Ditching	0.103
Locomotive repairs	0.232
Driver boss	1.090
Stable boss	0.305
Engineers	0.013
Electrician	0.096
Timekeeper	0.172
Roller men	0.302
Special work	3.692
Total	25.063

Category	Total Cost, Pct
Locomotive drivers	3.443
Rope riders	1.613
Hoistmen	1.934
Chute loaders	2.401
Trackmen	1.578
Miscellaneous labor	2.532
Total	13.501

Tipple

Category	Total Shifts, Pct
Locomotive engineer	0.249
Weighman	0.424
Dumper	0.666
Car coupler	0.610
Crusher tender	0.318
Jig operator, V jig	0.418
Jig operator, B jig	0.553
Air tables	0.060
Greaser	0.311
Cleanup	0.951
Slurry operation	0.828
Furnacemen	0.441
Dryers	0.819
Box car loading	0.371
Scalemen	0.374
Car slabbers	0.474
Slack loading	0.311
Trackmen	0.441
Sampler	0.176
Rejects	0.262
Repairs	0.053
Maintenance	0.656
Special coal loading	0.716
Warehouse, foremen, engineer, electrician, timekeeper, watchman	2.356
Total	12.837

Category	Total Cost, Pct
Preparation plant	5.470
Loading	1.801
Miscellaneous labor	1.489
Total	8.760

Additional

Category	Total Shifts, Pct
Plant heating and compressors	1.640
Machine shop	3.827
Supervision	
Administration	
Selling	
Office	
Total	3.420
Total labor	100.00

Category	Total Cost, Pct
Plant heating and compressors	1.468
Machine shop	2.229

Summary

Total labor costs*	69.744
Purchase power	7.035
Stores and materials	12.194
Administration, including executive salaries, royalties, taxes, insurance, selling expense, pension costs, welfare fund costs, etc.	11.027
Total	100.00

* Labor costs have been loaded to include Workmen's Compensation Board payments, holidays, Unemployment Commission costs, and medical aid. Costs do not include depletion or depreciation.

The first power tool was the air pick, still widely used, which was introduced in the 1920's together with air drills. Air-powered locomotives were generally used for haulage, as they are today, air being supplied at 700 to 1000 psi from charging stations throughout a mine. Trolleys have not been allowed for safety reasons, but for short hauls or gathering some battery locomotives of permissible type have been introduced. In the last 10 years permissible diesel locomotives have come into increasing use. Vastly superior to air locomotives, diesels have the flexibility of the battery locomotive, if not the power of the trolley. The largest diesels now in use are 15-ton machines with 100-hp engines.

Both in mining and conveying to main entries, development has been slow and arduous. No mobile machinery available as yet is effective on a pitch greater than 5°, which eliminates any self-propelled equipment. It was necessary to attempt mechanization along other lines which would suit conditions in various seams. Examples follow.

Panel Method: As shown in Fig. 4, two places are driven at 60-ft centers, up the pitch from the main entry. In one place a hoist and track is installed for hauling materials, and a chain conveyor is installed along the track, feeding to a loading chute at the main entry. The places are driven about 1300 ft, and three 400-ft conveyors are used in tandem. The top 100 ft of coal is fed to the last conveyor by chute. As the inclines are driven, rooms are broken off on each side. Rooms on the left side are completed and pillars pulled on the advance, and when the inclines

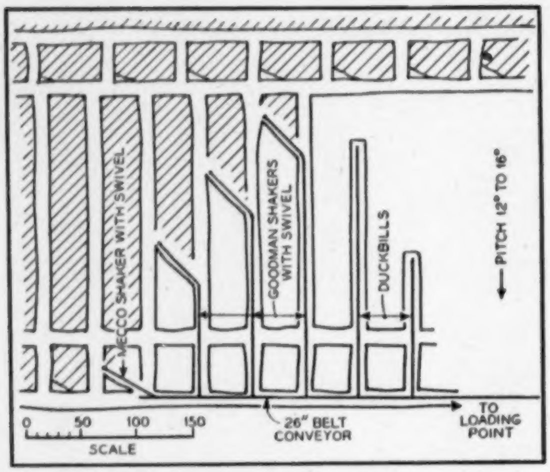

Fig. 6—Seam with poor roof and moderate pitch of 12° to 16°.

are finished, rooms and pillars on the right side are mined out on the retreat. In this instance, where roof is good, rooms are driven 30 ft wide and a 40-ft pillar taken on the retreat, with a 15-ft sacrifice pillar left in. This means that rooms are actually driven on 85-ft centers. Rooms and pillars are cut with shortwall cutters and loaded out to the incline conveyors by duckbills, the coal sliding down the footwall to the duck, which lies along the low side rib of the room. Timbering is by prop and cap piece, on 4-ft centers, which are increased to 4x5-ft spacing immediately over conveyors. In such a system five duckbills are used, four producing and one on the move.

Fig. 5 illustrates this system. One of the two inclines driven up the pitch carries the chain conveyors and hoist and supply track. Rooms are driven off the incline at 60-ft centers, a 250-ft block is left, and another pair of rooms is driven. This system is repeated to the top of the district. Rooms 5, 6, 7, 8, 9, and 10 are driven on an average pitch of 5° for a distance of 300 ft, shaker conveyors being used. A raise is then put through from rooms 5 to 7 and 7 to 10, and a belt installed in room 6, delivering to a chain conveyor in the primary incline. Rooms 5 to 10 are then advanced another 300 ft, with shakers, the coal from room 6 being delivered directly to the belt and the coal from rooms 7 to 10 coming down a chute in the raise to the belt in room 6. The belt is then extended 300 ft, raises are driven through to room 10, and the process is repeated until the full room length is 1000 ft, room 6 having 750 ft of belt conveyor and 250 ft of shaker conveyor. The same method is carried out at the same time with rooms 1 to 4, the coal from room 5 coming out through room 1. At the end of the 1000-ft panel pillar extraction is started in room 8 from the last raise. Coal is cut straight up the pitch with long wall cutters, with an effective cut of 5 ft. The operation commences at midnight when two machine men lower the longwall cutter from the top to the bottom of the face and then proceed to cut up the pitch. They complete the cut and leave the machine anchored at the top of the wall.

On day shift four miners work on the face. A prop bulkhead is erected in the room below the cut coal. This is to allow controlled feeding of the coal through the bulkhead and onto the shaker conveyor in the room. The entire 250-ft face is then drilled and shot. The coal settles down on the footwall but otherwise does not move down the pitch. By removal of bug dust with a scraper at the bottom of the wall, space is made to insert a sheet iron which is spiked to the shale footwall. The coal is then started by barring or by use of air picks. When sufficient coal has been removed, another sheet iron is placed and more coal sent down the wall. This operation is carried on to the top of the wall, the work being finished on the afternoon shift by four more miners whose last job is to remove sheet iron and make the place ready for the cutting crew. Props are set as coal is removed. If from experience a place is judged ready to cave, cutting is commenced in the next raise and pillar extracted toward the cave until only a chain sacrifice pillar is left.

Similarly extraction is carried out in room 6, but following 100 ft behind room 8. If necessary part of the pillar between rooms 7 and 8 is left to hold back gob. Meanwhile timber is taken from the supply incline along the upper room of a wall and then down the pitch to where it is required.

In the lower rooms coal is pulled through room 1, but the pillar between rooms 5 and 6 is left in to stop gob slides from above.

If it is desirable, longwalls can be taken out on the other side of the primary inclines and the area sealed off above the main return airways. The method can be applied only to areas having good roof. It has not been attempted in seams thicker than 8 ft.

Seam with Poor Roof and Moderate Pitch: Fig. 6 shows a method of taking out rooms and pillars in a seam 14 ft thick, pitching 12° to 16°, with friable coal and a weak shale roof having many slips. A pair of rooms is driven at 5° across the pitch and a 250-ft block left to the next pair of rooms. The rooms are driven 300 ft with duckbills and shortwall cutters, and a crosscut is driven every 150 ft. A belt is then installed in the lower room and the room is advanced another 300 ft, and so on, to a total length of 1000 ft. Coal from the upper room is taken to the belt by a shaker conveyor in a crosscut. Rooms are not more than 12 ft wide, crosscuts are 10 ft, and places are driven 10 ft high. Minimum timbering requirements are sets on 4-ft centers, with lagging between collars and also between high side legs to retard sloughing, cr, in pillars, props, at 4-ft centers with 3x8x18-in. cap pieces.

From the inby end of the rooms, splits are driven 12 ft wide straight up the pitch with duckbills and shortwalls. When the end split is driven through, the duck and shortwall are taken out, and a swivel installed as indicated in Fig. 6. The pillar is taken out by a series of narrow skips made by air picks and shooting. The pan line is kept alongside the face of the skip and coal either shoveled or shot onto it. The duckbills cannot be used at this stage because of the necessity of props at a maximum of 4-ft centers in every direction. It has not yet been determined whether roof bolting is the answer to utilization of duckbills in these pillar conditions.

The same method is used with split 2. Meanwhile another pan line is installed in split 3, and the duckbill and shortwall from split 1 used in split 3; the duck and cutter from split 2 are used in split 4.

Productivity under any of the methods described above is much the same. Typically, the results are as follows. Costs are divided as shown in Table III.

Raw coal per man day overall	4.60 tons
Refuse loss at preparation plant, 10.5 pct	0.48 tons
Net production clean coal per man day	4.12 tons

Table III. Costs of Mine Production from Pitching Seams by Mechanized Methods

Mining

Category	Total Shifts, Pct
Contract miners	10.647
Company miners	24.745
Timbermen	3.555
Timber packers	2.036
Rock dusting	0.587
Ventilation	1.484
Pumpmen	0.345
Pipe fitters	0.656
Handling materials	1.225
Washhouse and lamphouse	0.621
Maintenance	0.621
Mine timber	0.311
Warehouse	0.362
Mechanics	0.794
Laborers	1.225
Supplymen	1.363
Administration	0.259
Pit bosses	1.329
Fire bosses	3.986
Engineers	0.569
Electrician	0.173
Timekeeper	0.173
Safety supervisor	0.173
Total	57.239

Category	Total Cost, Pct
Contract miners	8.393
Company miners	17.076
Timbermen	2.349
Timber packers	1.320
Miscellaneous labor	11.498
Total	40.636

Haulage

Category	Total Shifts, Pct
Locomotive driver	1.881
Rope rider	0.604
Tuggermen	1.087
Track layers	1.363
Pipe fittters	0.863
Chute loaders	0.293
Chute builders	0.414
Hoistmen	2.744
Sandmen	0.362
Car repairs	0.259
Driver boss	0.328
Electrician	0.690
Conveyor runners	3.158
Beltmen	0.880
Conveyor movers	3.814
Laborers	1.363
Pushermen	0.173
Total	20.276

Category	Total Cost, Pct
Locomotive drivers	1.198
Rope riders	0.384
Hoistmen	1.770
Chute loaders	0.189
Track layers	0.873
Miscellaneous labor	8.577
Total	12.991

Tipple

Category	Total Shifts, Pct
Motormen	0.155
Weighmen	0.794
Dumper	0.293
Car coupler	0.155
Jig operator	0.466
Oiler	0.173
Cleaner	0.155
Dryer	0.310
Box car loader	0.294
Car handler	0.155
Assayer	0.311
Repairs	0.638
Maintenance	1.984
Laborers	2.468
Firemen	0.311
Electrician	1.208
Watchman	0.570
Mechanic	0.690
Foreman	0.673
Truck drivers	0.535
Distributors	0.535
Cat operators	0.345
Total	13.218

Category	Total Cost, Pct
Handling coal	0.994
Cleaning	1.488
Loading	0.282
Miscellaneous labor	5.727
Total	8.491

Additional

Category	Total Shifts, Pct
Plant heating and compressors	1.243
Machine shop	4.884
Supervision	
Administration	0.552
Selling	0.345
Office	2.243
Total	3.140
Total Labor	100.000

Category	Total Cost, Pct
Plant heating and compressors	0.694
Machine shop	3.184

Summary

Total labor costs*	66.196
Purchase power	5.076
Stores and material	13.904
Administration, including executive salaries, royalties, taxes, insurance, selling and office expense, pension and welfare fund costs, etc.	14.824
Total	100.000

* Labor costs have been loaded to include Workmen's Compensation Board payments, holidays, Unemployment Commission costs, and medical aid. Costs do not include depletion or depreciation.

Power costs are less in the mechanized mine than in the non-mechanized mine, which pumps and hoists to a far greater extent.

It is apparent that mechanization has not brought about outstanding results as compared to results obtained with hand-held portable tools, e.g., the pneumatic pick. It should be remembered that gravity is always fighting attempts at mobility. For instance, in a seam pitching 30°, moving a duckbill, pan line, drive, and shortwall cutter from a finished place and setting up in a new location 500 ft up the pitch will take up to 15 manshifts of labor.

However, without conveyor systems, cutters, and loading equipment, mines having seams with a non-running pitch could not compete with mines having seams of running pitch, other factors being equal.

Attempts at mechanization are thwarted for other reasons. The use of face equipment may result in high production per man day when wide places are being worked or pillars taken out, but production drops sharply in tight work places, which may be only 10 or 12 ft wide. Because complete cutting and loading equipment must be installed for each place, cost is high per ton produced. Equipment is utilized for only part of each shift because of timbering requirements. For example, under heavy roof a set must be put up as soon as coal has been removed to allow for it and the roof lagged from set to set.

Also, during the life of the industry a wage structure has been developed which includes contract rates for miners. In a mechanized mine the face worker is on day wage. So far no incentive system has been developed which is satisfactory. Equipment is not mobile and requires much manual labor to operate and move. At the same time the investment is very high per ton of coal produced. If the operator's investment in machines is to be justified, it appears necessary to establish an incentive rate that will encourage the worker to obtain maximum production from machines.

The surface plant at International mine, Coleman Collieries Ltd. at 4200-ft elevation. Inset shows the road to Tent Mt. strip pit (indicated by arrow) at 7000-ft elevation.

It is regrettable that mechanization does not show up to better advantage. The question arises as to what can be done to improve the situation. Great effort has been made in attempting to adapt equipment to pitch conditions, but available equipment is not the answer. Chiefly, lightness is required, and conveyors, whether belt structures, shakers, or flight conveyors, including the drives, must be developed to have capacity and strength with much less weight. As mobile equipment is out of the question, semi-mobile cutters similar to the German *Eikhoff* appear desirable. This small light machine includes self-propelled crawler treads and an inbuilt winch to pull itself to the face, with hydraulic jacks for holding position and a retracting universal cutter head.

Even with light equipment, tight work will be a problem. A place which can be held only 10 or 12 ft wide may be cut in a few minutes, yet 2 hr may be required to maneuver a shortwall cutter to the face and away again. Experiments are now being carried out in shooting complete faces from the solid by suitable patterns of split-second delay action shots. For tight work there is a promising place for such methods, provided that there is adequate ventilation, proper rock dusting or wetting, and correct shooting equipment and materials, handled by competent shotlighters.

As in all mines, transportation is steadily improving. Light-weight high-capacity mine cars with roller-bearing wheels are hauled by diesel locomotives, traveling on better track.

Reference to cost distribution shows that a considerable percentage of total manpower is utilized on surface. To date this has been unavoidable, as the coal must be washed, and in these climatic conditions dried, a major problem because the generally friable coal runs largely to fines. Preparation plants are adequate but because they have been developed over many years by additions and changes large staffs are necessary. Future mines with well-designed plants will undoubtedly improve greatly on throughput per manshift.

Electric power underground replaces compressed air at a saving of 5 to 1 and greatly improves machine operation. For percussion machines such as picks, drills, and rock drifters, compressed air is better than electricity, but to keep piping at a minimum it is probable that in concentrated production areas continued use of electric-powered portable compressors will be preferred.

Experimental drilling of crosscuts and breakthroughs has been conducted with large-diameter augers. Future use of such equipment is problematical because of the relatively cumbersome machinery and the requirement that a seam be uniform and free of *sulphur balls*.

Although it is not foreseeable that overall costs or output per man day can approach production under flat seam conditions, it is possible that output can be increased 50 pct, i.e., from 4 to 6 tons, by use of adequately designed lighter equipment and development of semi-mobile machines.

Acknowledgment

Acknowledgment is made to T. G. Ewart and T. H. Wilson of Crow's Nest Pass Coal Co., Fernie, B. C., and to A. E. Graham, E. Price, and R. Upton of Coleman Collieries Ltd., Coleman, Canada.

Collection of Laboratory Dusts

by Benny Langston and Frank M. Stephens, Jr.

Although little information is available concerning small-scale equipment for dust collection in laboratories, it is possible to adapt standard equipment for laboratory use. Dust from laboratory processes may be collected by cyclone separators, filters, electrostatic separators, scrubbers, and settling chambers.

IN recent years much attention has been given to recovery, treatment, and disposal of dusts discharged into the atmosphere from operations of industry. Considerable data has been accumulated on both operation[1-4] and design[5,6] of dust-collector equipment for commercial installations. On the other hand, there is almost no published data on design and construction of small-scale equipment to handle dust problems that arise in the ore-dressing laboratory.

Dust-collection equipment such as multiclones, single-cyclones, scrubbers, chemical and mechanical filters, settling chambers, and electrostatic separators has proved its efficiency for collecting dust in industry. In the laboratory, however, the engineer is faced with the problem of collecting small quantities of dust, inexpensively, without diverting the major effort from the metallurgical problem to the problem of collecting dust produced by the process.

For most applications standard dust-collection equipment is too large for use in the laboratory; however, for control of dust in large working areas it is often possible to use a standard dust collector, such as an air filter, with branch ducts to eliminate a health hazard. For example, the well-furnished sample-preparation room containing small jaw crushers, rolls, and pulverizers, in addition to the riffles and screens necessary for preparation of samples, presents a perennial source of dust.

The authors' experience has shown that a combination system consisting of overhead branch ducts to the individual equipment and floor ducts with grills, where applicable, connected to a central dust collector effectively removes dust generated in preparation of samples.

Fig. 1 is a sketch of a downdraft dust-collector for table installation. Similar systems can be built with floor grids. For portable equipment such as laboratory vibrating screens this type of installation with a steel grill to support the heavy load is reasonably efficient. Overhead branch ducts to individual crushing and grinding equipment, although efficient, must be carefully controlled by dampers to prevent excess loss or a change in the composition of the sample. Change in sample composition can result from excess velocity, which causes selective removal of constituents of low specific gravity.

Fig. 2[7] shows the theoretical effect of terminal velocity on spherical particles of different specific gravities in air and water under action of gravity. Fig. 3 shows the effect of air velocity on composition of $CaCO_3$ coal mixtures.

Although the entrainment of dust particles in a moving air stream is the basic mechanism by which all dust-collection equipment functions, usually intake velocity of the dust-collection system must be controlled to prevent loss of part of the sample.

As an example of what may happen when excess velocities are used, a mixture of 50 pct coal and 50 pct limestone was crushed to −10 mesh and fed to a pulverizer equipped with an overhead dust-collection system. Fig. 4 shows the overhead dust-collection equipment used in this test. The pulverizer was set to give a product 95 pct −100 mesh in two stages. Velocity of air passing over the lip of the pulverizer was measured with an anemometer. After grinding, the finished product was analyzed to show the amount of calcium carbonate present. Fig. 3 shows graphically the increase in calcium carbonate as velocity through the dust-collection duct was increased. These data show that at a velocity of 1 ft per sec little if any of the coal was entrained by the overhead draft. At the maximum velocity, about 6.5 ft per sec, approximately 7 pct more coal was entrained than calcium carbonate.

From an operating standpoint, this problem can be remedied easily by dampering the line to control velocity. The lowest velocity commensurate with satisfactory dust control should be used to prevent excess loss and, in some cases, selective dust loss.

Collection of Dust in Laboratory Processes

As in industry, the engineer desires to collect efficiently the dust produced by processes being investigated on a laboratory scale. However, in the collection of laboratory dusts he is faced with two additional problems: 1—The volumes of gas and the quantity of dust that must be recovered are small when compared with the capacity of standard dust-collector equipment, which must be scaled down in design except for collection of dust from large pilot-plant operations. 2—In addition, because of the variety of problems studied in the process laboratory, the engineer cannot design today a dust collector that will meet the conditions imposed by the processes of tomorrow. Sometimes, therefore, he must compromise collection efficiency to minimize the cost of fabrication and the amount of time diverted from the metallurgical to the dust-control problem.

For collection of dust from laboratory processes a cyclone separator, filters, electrostatic separators, scrubbers, and settling chambers can usually be adapted for small-scale operations. The following

B. LANGSTON, Junior Member, AIME, and F. M. STEPHENS, Member AIME, are associated with Battelle Memorial Institute, Columbus, Ohio.

Discussion on this paper, TP 3805B, may be sent, (2 copies) to AIME before Oct. 31, 1954. Manuscript, Feb. 23, 1954. New York Meeting, February 1954.

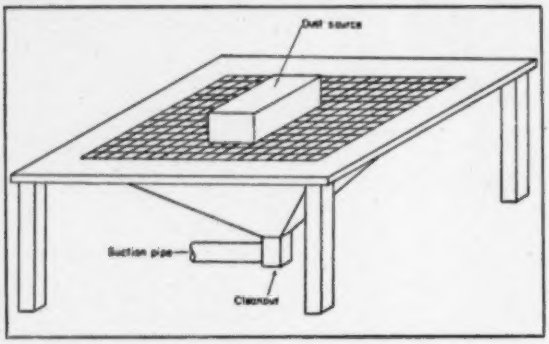

Fig. 1—The downdraft method of dust control.

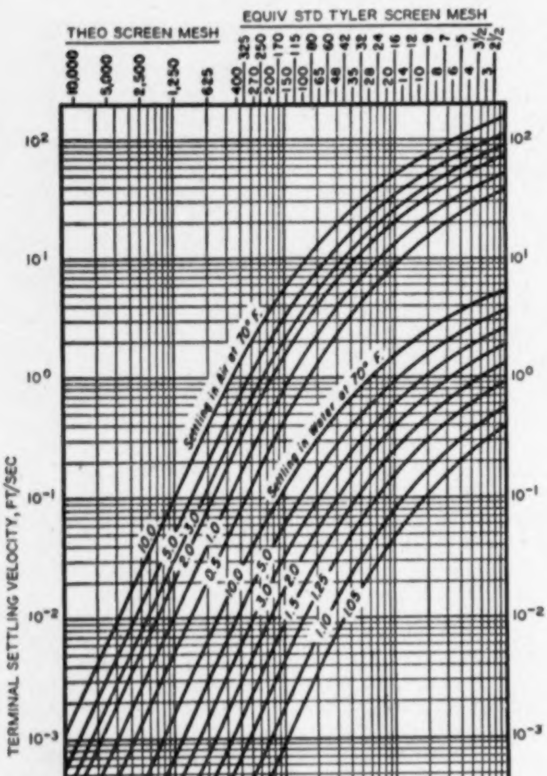

Fig. 2—Terminal velocities of spherical particles of different density settling in air and water at 70°F under the action of gravity. Numbers on curves represent true (not bulk or apparent) specific gravity of particles referred to water at 4°C. The Stokes-Cunningham correction factor is included for fine particles settling in air.

sections describe some of the fundamental concepts involved in the design and fabrication of small units of each of these collectors. Several examples are given to show problems characteristic of a small-scale dust collector.

Cyclones: The size of a cyclone is governed primarily by volume of gas and sizes of particles in the dust load, but the main variable determining the collecting efficiency is the centrifugal force applied to the gas stream. In the laboratory where small volumes of gas are encountered and reasonable collection efficiencies are desired, the cyclone must be small in diameter to obtain the pressure drop and applied centrifugal force required for efficient collection of dust.

The fabrication of laboratory cyclones is simple in that black iron sheet, which can be sheared and rolled easily, will withstand the temperature and corrosion conditions normally encountered in laboratory dust collection. Fig. 5 shows the proportions generally employed in construction of a cyclone, as well as a modified design of the standard type. Experience has shown that some improvement can be achieved in the collection efficiency obtainable in a small cyclone by starting the tapered section one diameter from the top of the cyclone rather than the normal two diameters.

The small cyclone does present certain operating problems. For example, because of the small opening for discharging the dust, fine dust with a high angle of repose tends to bridge and plugs the discharge. Laboratory expedients for preventing bridging include installation of external vibrators or internal moving chains sealed by a packing gland. These can be operated periodically to keep the dust moving. Another problem encountered in operating small cyclones is the plugging of the inlet tubes, and it is often advisable to equip the cyclone with access tees to allow for periodic cleaning of the entrance line.

Filters: Cloth bag filters have been used for many years for the collection of dust. Once a suitable filtration bed has been established by deposition of dust on the cloth surface, collecting efficiency is reasonably constant under variable operating conditions. As in industrial applications, the chief concern in the application of bag houses to collection of laboratory dusts is the estimation of resistance of the filter, the time cycle for cleaning, and the selection of proper filtering media.

In the construction of a laboratory bag filter, the most important factor is selection of the proper filtering media. Usually this automatically determines the filter resistance and the time cycle for cleaning. The writers' experience has been that temperature of the gases, particle size of the dust, corrosive properties of the gas and dust, and humidity are the main factors to be considered in selection of the filter media.

When a bag house is used for laboratory dust collection, the dust-laden gases pass into socks constructed from material which will stand the conditions of temperature and corrosion. The exhaust fan sucks the gases through the filter media and dust is collected in the hopper. An advantage of this method is that proper selection of the exhaust system, uneconomical in a commercial plant, increases flexibility of the equipment for use in the laboratory. Another advantage of the system is that passing the gases downward collects the dust deposited on the

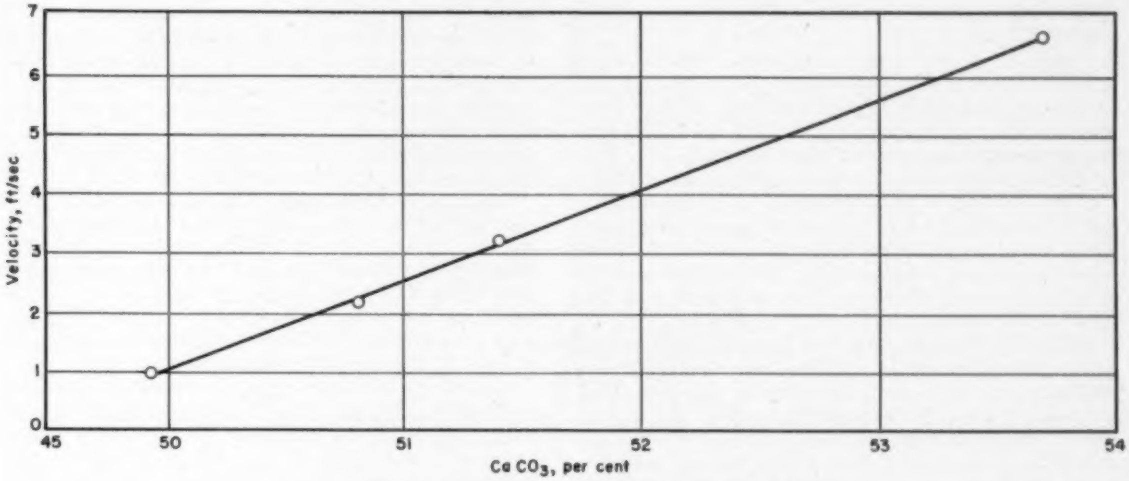

Fig. 3—Effect of air velocity on composition of $CaCO_3$ coal mixtures.

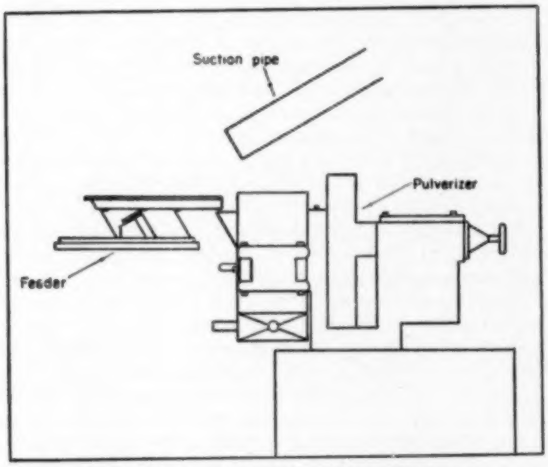

Fig. 4—Equipment for overhead dust collection.

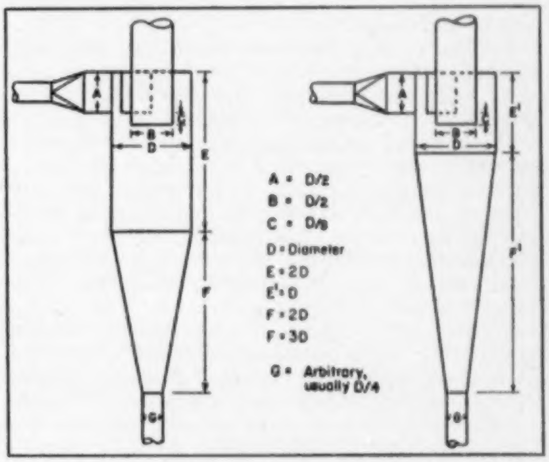

Fig. 5—Standard collector (left); modified design (right).

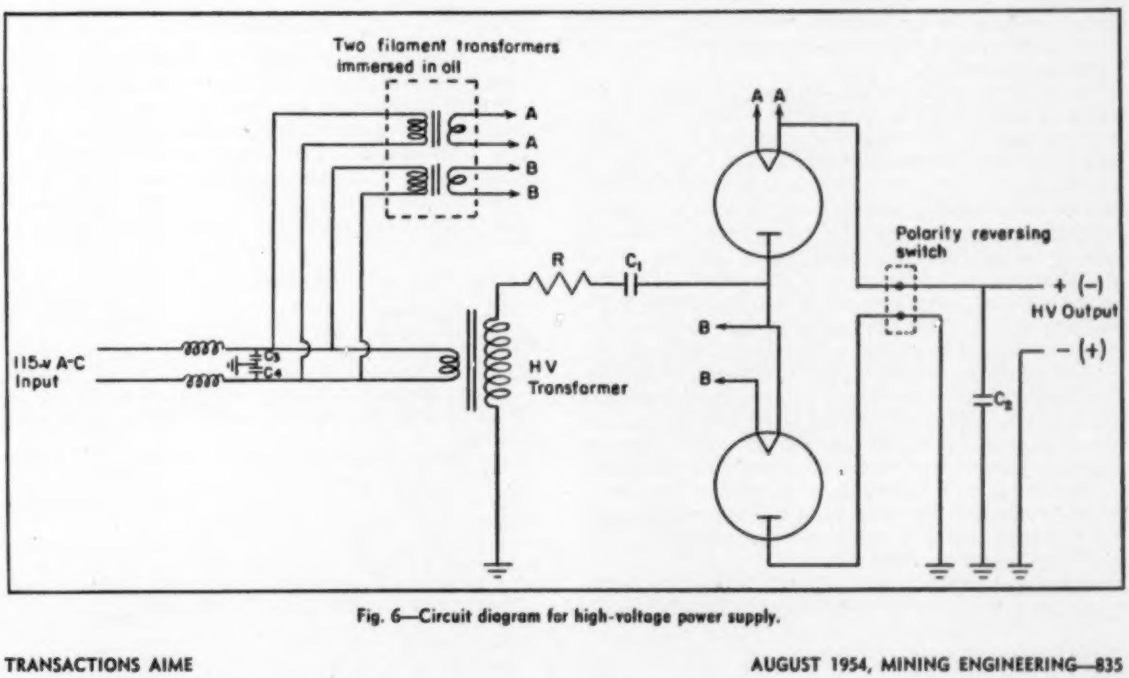

Fig. 6—Circuit diagram for high-voltage power supply.

filter media without passing it through an upward current of gas.

Recently the development of woven asbestos and glass has materially improved construction of the laboratory bag house for the collection of dust from gases having a temperature as high as 275°F and requiring an acid-resistant filter media.

Although mechanical tappers can be used to clean the bags, in the laboratory where continuous cleaning of the bags is a luxury, manual tapping decreases the cost for construction of the bag house. In some processes where gases are cool and noncorrosive an ordinary vacuum cleaner can be employed as a bag filter to recover small quantities of dust.

Electrical Precipitators: For general performance under widely varying conditions the electrical precipitator has no equal. Admittedly the dust load should not exceed 10 grains per cu ft of gas for maximum collection efficiency. However, if dust concentrations greater than this limit are encountered, installation of a cyclone in front of the Cottrell will reduce the dust load to a point where collection efficiencies approaching 99 pct of the dust in the gas stream may be obtained.

The electrical precipitator consists of four principal parts: 1—a source of high voltage, 2—the high-voltage ionizing electrodes and associated collecting electrodes, 3—equipment for collecting the dust, and 4—a shell to house the precipitator. One of the major factors in the construction of a laboratory precipitator is the power source. In a tube-and-wire precipitator the shell and the discharge hopper to collect the dust can be constructed readily from rolled black-iron sheets. It may be either a single tube or twin tubes 6 in. or less in diam, depending on the volume of gas that must be treated. The ionizing electrode usually consists of a Nichrome or Chromel A wire of 22 gage or smaller. Normally wire-and-plate precipitators are not used in the laboratory unless relatively large volumes of gas must be treated.

Although the advice of an engineer familiar with electronics is advantageous when a power source is constructed for a laboratory precipitator, it should be possible for the average engineer to build a suitable power source by following the circuit diagram shown in Fig. 6. The diagram shows a unit that can be constructed from materials available to the average laboratory.

An 8000-v transformer, originally designed for igniting an oil burner, is used as a source of high-voltage power. Two 30,000-v, 500-micromicrofarad television filter condensers (C_1 and C_2) are used to isolate the transformer secondary from the load in the circuit, thereby preventing an overload when the high-voltage output is shorted, as so frequently occurs under operating conditions. Secondaries of the filament transformers are insulated from primary windings and ground to withstand the high-voltage output. The two transformers used for this purpose, both Merit Coil & Transformer Corp. No. P2942, are immersed in oil for additional protection. To protect the circuit when the Cottrell is discharged, two 0.05-microfarad condensers and two choke coils, consisting of 100 turns of No. 24 cotton-covered enameled wire on a ½-in. core, were placed in the power-input line. The rectifier tubes are Type 8020. This circuit will provide a 14,000-v power supply for use with single or twin-tube precipitators, varying from 4 to 6 in. diam.

Care must be taken in the installation of the ionizing wire to prevent shorting of the circuit by build-up of the dust between wires and shell. This can be remedied by placing a small vibrator on the precipitator shell, but the authors' experience has been, particularly with up-draft precipitators, that continuous vibration lowered collection efficiency. For this reason the vibrator is operated only at periodic intervals, depending on the dust load, for sufficient time to relieve dust flocculated on the shell.

Often it is advantageous to have cleanout ports near the entrance and exit ports of the Cottrell. For example, in the collection of dust from a sulphating roast, gases contain iron oxide as dust and sulphur trioxide as a mist. Under certain temperature conditions the iron oxide and sulphur trioxide form ferrous sulphate, which plugs the Cottrell and stops all passage of gas until the unit is cleaned out.

Scrubbers: Although in many cases the scrubber is efficient as a dust collector, several disadvantages limit its use in the collection of laboratory dusts. Large volumes of water or chemical reagent must be passed through the scrubber to keep the solids from plugging the discharge port. In the laboratory, where it is often desirable to recover and analyze the dust, use of a scrubber requires filtration of the solution to recover the solids. In the case of chemical reagents, any corrosive solution must be neutralized prior to disposal down laboratory drains. Also, if the dust contains soluble values and the process requires analysis of the chemical solutions to obtain metallurgical balances, the large volumes of solution give such a low concentration of values that accurate determinations are difficult if not impossible. In essence, although the scrubber has proved a good commercial dust collector, in the laboratory other methods appear to have the advantage.

Settling Chambers: The settling chamber basically reduces the velocity of the gas stream from a velocity which entrains dust to one at which the solids will settle. For this reason it is probably the simplest of all dust collectors. However, because its practical applicability is limited to removal of particles larger than 50 to 100 microns, its use in the laboratory is limited to applications where it is not necessary to remove all the dust prior to exhausting the gas.

Conclusions

As indicated by the discussion on each of the individual types of dust-collecting equipment, there is no single solution to the problem of collecting the small quantities of dust produced by laboratory processes. However, by utilization of available equipment and application of ingenuity and good engineering judgment it is usually possible to overcome the problems that exist in collection of laboratory dusts.

References

[1] W. H. Dennis: Dusting in the Copper Smelters. *Mining Magazine* (1947) **77**, pp. 16-22, 78-80.

[2] W. H. Dennis: Fume and Dust in Lead Smelting. *Mine and Quarry Engineering* (1947) **13**, pp. 237-242.

[3] L. C. McCabe: Control of Open Hearth Fumes. *Industrial Engineering Chemistry* (March 1951) 89-A to 92-A.

[4] H. V. Welch: The Fume and Dust Problem in Industry. *Journal of Metals* (1949) **12**, pp. 213-236.

[5] C. F. Montross: Entrainment Separation. *Chemical Engineering* (1953) **10**, pp. 213-236.

[6] J. M. Dalla Valle: Dust Collector Costs. *Chemical Engineering* (1953) **11**, pp. 177-183.

[7] J. H. Perry: *Chemical Engineers Handbook*, 3rd ed., p. 1017. McGraw-Hill Book Co., New York, 1950.

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Industrial Minerals Division—Lake Placid Fall Meeting

The Industrial Mineral Division's Fall Meeting at Lake Placid, N. Y., October 5 to 9 is getting close. Plans have reached the final stage and the program is being whipped into shape.

The entire first day of the meeting will be given over to registration at the Whiteface Inn, meeting headquarters. While the list of papers is not yet complete, the program is already taking shape.

Program as of July 1954

WEDNESDAY, OCTOBER 6

Technical Session

Morning

1. **Geology of the Adirondacks**
   by Matt S. Walton, Jr.
2. **Mineral Economics of Upstate New York**
   by John A. Graham
3. **Geological Control of Adirondack Mineral Deposits**
   by A. E. J. Engle

Afternoon

1. **Anorthosite as an Industrial Mineral**
   by J. G. Broughton
2. **Operations of International Talc Co.**
   by F. G. Keuhle and Roger Miller
3. **Magnetic Anomalies and Geophysical Prospecting in the Adirondacks**
   by LeRoy Scharon
4. **Origin of Titaniferous Magnetites**
   by J. L. Gillson

Social Hour

Evening

Games before and after dinner.

THURSDAY, OCTOBER 7

Technical Session

Morning

1. **Wollastonite and Diopside, New Industrial Minerals**
   by Raymond Ladoo
2. **Commercial Colored Slates of New York and Vermont**
   by D. M. Larrabee
3. **Geochemistry and Importance of Saratoga Mineral Waters**
   by Lester W. Strock
4. **Quality Control in the Manufacture of Extender Pigments**
   by Charles H. Pratt

Afternoon

Field Trip

Social Hour

Evening

Film on Northern New York following dinner. Swimming in heated pool.

FRIDAY, OCTOBER 8

Technical Session

Morning

1. **Industrial Minerals of the Ottawa Valley**
   by N. B. Davis
2. **Gypsum Deposits at Dutch Settlement, N. S.**
   by C. Olivier Campbell

Afternoon

Social Events and Sports

Prize competition in various sports and noncompetitive games and activities.

Social Hour

Evening

Farewell Banquet

SATURDAY, OCTOBER 9

Full day of Field trips

Ladies' Program

WEDNESDAY, OCTOBER 6

10:00 am

Coffee Hour

Afternoon

Bingo, Bridge, Canasta (Prizes)

THURSDAY, OCTOBER 7

Morning

Shopping, sight-seeing around Lake Placid

Afternoon

Whiteface Memorial Highway bus trip to Tower. Side visit to Santa Claus Village

Minerals Beneficiation Division

San Francisco Fall Meeting

The tentative program has been completed for the Fall Meeting of the Minerals Beneficiation Div., in San Francisco, September 24. The meeting follows the American Mining Congress Convention scheduled earlier in the same week.

Registration for the MBD gathering will be $3.00 to members and $1.00 for students. A special desk will be set up at the Mining Congress to take care of MBD registration. It will also be possible to register at the Fairmont Hotel on the day of the Fall Meeting.

Program

Data as of July 1954

FRIDAY, SEPTEMBER 29

Technical Session

Morning

1. **Ring Formation in Rotary Kilns**
   by F. A. McGonigle and S. J. O. Carroll
2. **Control Instrumentation in a Uranium Plant**
   by Glenn Mustee and J. L. Lake
3. **Sampling and Assaying Tungsten at Getchell**
   by Keith Kunze and Ray Nojima
4. **Flow of Bulk Solid**
   by A. Jenike

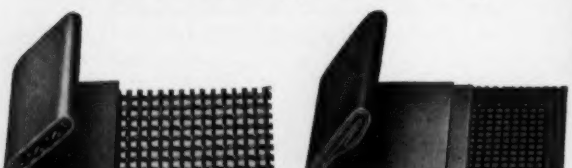
Noon

Luncheon, Fairmont Hotel

Afternoon

1. **Silver Bell Concentrator**
   by Norman Weiss
2. **Liquid-Solid Cyclone in Closed Circuit Grinding of Concentrates**
   by F. M. Lewis and E. C. Johnson
3. **Molybdenite Recovery at Morenci**

Tyler Screen Sections for All Makes of Screening Machines!



Screen sections of Tyler Woven Wire are fabricated for all makes of vibrating screens in any mesh or metal. They are made up with hook-strip or bent-edge construction to suit the machine on which they are to be used.

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Old Timers Award Presented To Virginia Polytechnic Student

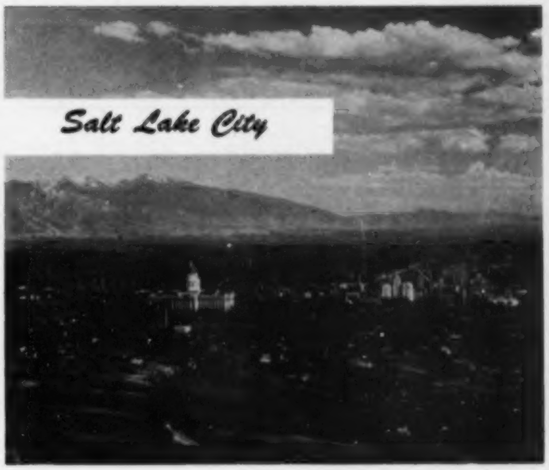
M. D. Cooper, Chairman of the Coal Div. of the AIME, and secretary of the Old Timers Club, presents the Old Timers Award and engraved watch to Ellis Paxton Bucklen, a senior in mining engineering at Virginia Polytechnic Institute. Dean Emeritus E. B. Morris assists in the ceremony.

WITH less than two months to go before the Rocky Mountain Region Industrial Minerals Conference, program and plans are almost in final shape. The meeting is scheduled for October 28 to 30, with headquarters at the Newhouse Hotel, Salt Lake City. Committee members expect a large turnout.

Registration will take place Thursday afternoon, October 28. Three technical sessions, football, and the Utah Section Annual Dinner Dance promise to give those attending a full week end.

Salt Lake City has long enjoyed a reputation as one of the most hospitable cities in the U. S. The local section is doing its best to see that the reputation is enhanced. J. Bracken Lee, Utah Governor, will be the featured speaker at the Industrial Minerals Luncheon Friday.

The list of technical papers promises to cater to a variety of interests. Industrial water, industrial minerals, titanium, open pit operations, and other aspects of the mineral industry are on the program.



Rocky Mountain Industrial Minerals Conference Program

Data as of July 1954

FRIDAY, OCTOBER 29

Technical Session

9:00 am

Co-chairmen—R. C. Talbott, manager, Raw Materials Development, Columbia-Geneva Steel Div., U. S. Steel Corp. and **R. R. Williams, Jr.,** assistant manager, Mining Dept., Colorado Fuel & Iron Corp.

1. **Industrial Water**
   by El Roy Nelson, vice president, First Security Corp.
2. **The Role of Industrial Minerals in Utah's Steel Industry**
   by John K. Hayes, supervisor, Raw Materials Exploration, Columbia-Geneva Steel Div., U. S. Steel Corp.
3. **Natural Gas in the Intermountain Area**
   by H. F. Hillard, chief engineer, Mountain Fuel Supply Co.
4. **Chemical Treatment of Ores**
   by C. A. Romano, resident manager, Intermountain Chemical Co.

Industrial Minerals Luncheon

12:15 pm

Speaker: Honorable J. Bracken Lee, Governor of Utah

Technical Session

2:00 pm

Co-chairmen—R. R. Williams, Jr., R. C. Talbott

1. **Titanium**
   by C. C. Blalock, mining engineer, Colorado Fuel & Iron Corp.
2. **Open Pit Phosphate Mining Operations**
   by Charles W. Sweetwood, mine superintendent, J. R. Simplot Co.
3. **The Production of Elemental Phosphorus via the Electrical Furnace Route**
   by J. L. Whiteside, plant manager, Monsanto Chemical Co.
4. **The Economic and Chemical Aspects of Cement Raw Materials**
   by John A. Wolfe, chief geologist, Research & Exploration Depts., Ideal Cement Co.
5. **Barite**
   by D. A. Power, manager, Minerals Development Div., Westvaco Mineral Products Div., Food Machinery & Chemical Corp.

SATURDAY, OCTOBER 30

Technical Session

9:00 am

Co-chairmen—J. M. Ehrhorn, director, Industrial Development, U. S. Smelting Refining & Mining Co. and **R. C. Cole,** plant manager, Vitro Uranium Co.

1. **Uranium in the Colorado Plateau**
   by Marvin L. Kay, vice president and general manager, Climax Uranium Co.
2. **What About Gilsonite?**
   by Park L. Morse, American Gilsonite Co.
3. **Gypsum in Utah**
   by W. S. Mole, Certain-teed Products Corp.

Football

2:00 pm

University of Utah vs University of Idaho at University of Utah Stadium, Salt Lake City. Buses will transport those attending game to and from Newhouse Hotel.

Dinner Dance

7:00 pm

Utah Section Annual Fall Cocktail Party and Dinner Dance, Grand Ballroom, Newhouse Hotel.

Around the Sections

• Members of the **Washington, D. C. Section** toured the Western Electric Co. plant at Baltimore, Md., on their annual field trip. Lunch was served by the company at the Point Breeze Works. B. N. Deaton, Western Electric Engineering personnel office, spoke briefly before the tour started.

• The recent field trip of the **Pikes Peak Subsection** took the members to Cripple Creek, where "Buck" Keil read a paper on the Carlton mill, followed by a tour of the mill itself. The ladies were conducted on a trip covering the historic points of the district. Cocktails, dinner, and an old-time melodrama, *Hazel Kirke* or *Adrift From Her Father's Love*, completed the day. Golden Cycle Corp. sponsored the cocktail party.

• Two films, *A is for Atom* and *Water—Pipe Line to the Clouds*, presented by the General Electric Co., Tucson, Ariz., were shown to members of the **Bisbee-Douglas Subsection** at a meeting held in Naco, Ariz. Two more films were seen by members at another meeting. The movies, *Heavy Rail* and *Indian Paint*, were presented by the Lee Redman Equipment Co. and Colorado Fuel & Iron Co. The subsection now has a membership of 98.

• **Philadelphia Section** members heard Felix B. Shay, vice president in charge of production, Foote Mineral Co., speak on *Lithium Mining and Refining in North Carolina and Virginia*. His talk was illustrated by Kodachrome slides. The meeting was the fourth and final one of the season for the mining group. Cocktails and dinner started the evening, with some 45 members and guests. Arrangements similar to those of this past season, where mining men and metallurgists on occasion held joint meetings, are planned for next year. AIME members coming to the Philadelphia area are urged to communicate with Ed Korostoff, Leeds & Northrup, 4901 Stenton Ave., or Joe Gillson at DuPont in Wilmington.

• New officers have been elected for the **Pennsylvania Anthracite Section**, and will serve for one year. They are: W. W. Everett, Glen Alden Coal Co., Chairman; Julian Parton, Lehigh Navigation Coal Co., Vice Chairman; and Floyd S. Sanders, Goodman Mfg. Co., Secretary-Treasurer. William H. Moore, Susquehanna Collieries Div., M. A. Hanna Co., was elected to the Executive Committee for two years to fill vacancy left by death of Frank Nicholson. Elected to the Executive Committee for three-year terms were: Walter Petzold, Hudson Coal Co.; Paul Goddard, Carey, Baxter & Kennedy Co.; George L. Wilmot, Wilmot Engineering Co.; Harold Wickey, Lehigh Valley Coal Co.; and George Holland, Jeddo-Highland Coal Co.

• Members and guests of the **Reno Subsection** of the **Nevada Section** met at the El Cortez Hotel for the last luncheon meeting of the spring season. Robert G. Reeves, acting secretary of the subsection, presided in the absence of Chairman John N. Butler. E. L. Stephenson, local consulting geologist, spoke on Nevada's geology and discussed his geologic map of the state soon to be released.

Bucyrus-Erie Co. has a 16mm sound-color motion picture, *These Users' Views*, that shows more than 30 different excavating, loading, and materials handling jobs done by the company's ¾ to 4-cu yd units. Models are treated in order of size. In applying for the film, the company would like to know when it is desired for a showing and if a modern 16mm sound projector is available. Write to Bucyrus-Erie Co., Publicity Dept., South Milwaukee, Wis.

• *Steel Tubes for Industry*, **a 16 mm sound movie, has just been released by Pacific Tube Co. of Los Angeles. One of the most fascinating aspects of this color film is the use of animated drawings to illustrate details of tube drawing and tube reduction. To obtain use of the film contact the Pacific Tube Co., 5710 Smithway St., Los Angeles 22.**

Pass Bylaw Revision Aiding Local Sections

The revision in Art. XI, Sec. 3, of the AIME bylaws, published in the April issues of the three Institute journals, was approved by the Board at its May 19 meeting. In short, the amendment removes the limitation of $400 as the maximum grant that may be given to a Local Section in any year.

The aid given to Local Sections who request it in 1954 consists of 50¢ per member on Jan. 1, 1954; half of the initiation fee received from all new members; and the first class railroad fare to and from the Annual Meeting for the Section Delegate. Aid to be granted in 1955 has not yet been decided upon in any of these three respects. Under the new plan, Local Sections should receive approximately $25,000 in 1954 if they get as many new members as last year, compared with $19,429 in 1953.

Committee on Nuclear Energy Proposed

Authority has been given the Secretary to survey the possibilities of organizing an AIME Committee on Nuclear Energy. It would be designed to further the interests of members involved in various activities connected with the nuclear energy program in such specific fields as exploration, mining, milling, extractive metallurgy, refractories, physical metallurgy, economics, and utilization. If sufficient interest is shown, the Committee will be organized, and it may be possible to have one or two sessions at the Annual Meeting next February in Chicago. Fall meetings might be organized jointly with similar groups in other societies, such as the ASME and the AIChE, each contributing papers for a day's sessions. Eventually the Committee might develop into a new Division of the Institute.

Those favoring the idea, or anxious to participate in the work of subcommittees, are invited to write to the Secretary of the Institute.

Consider AIME Meeting In Lima, Peru

A tentative proposal of the Lima, Peru, Local Section of the AIME that a meeting be arranged two or three years hence in that country was considered by the Executive Committee of the Institute at its June meeting. Doubt was expressed that a sufficient number of AIME members would be able to afford the expense or time that such a trip might require, to justify the extensive planning required. Living facilities for visitors at mining camps in the vicinity to which field trips might be taken were also believed extremely limited. The proffered hospitality of the Lima Local Section was deeply appreciated and if sufficient interest develops the matter will be reconsidered.

Two Mudd Books For New Junior Members

Currently, two books are given to new Junior Members of the AIME through the courtesy of the Seeley W. Mudd Memorial Fund. One, given to all such new members without specific request, is *A Professional Guide for Junior Engineers*, published by Engineers' Council for Professional Development, which has been widely acclaimed; the other is to be selected by the member from a list of several volumes in the various fields of the Institute, the most popular being a reprint of the Hoover translation of Agricola's *De Re Metallica*.

Personals

H. R. Gault is returning to Lehigh University, Bethlehem, Pa., as professor of geology after a leave of absence for a year as executive secretary, Div. of Earth Sciences, National Research Council, Washington, D. C. He will continue his work on carbonate rocks and basic rock alteration.

Sherman A. White is mine superintendent, Nickel Processing Corp., Nicaro, Oriente, Cuba. He was general manager for Industrial Minera y Metalurgica de Oaxaca, Mexico.

Otto von Perbandt has joined Wilmot Engineering Co., Hazelton, Pa., as a contracting engineer for the company's coal preparation equipment. Mr. von Perbandt, whose experience includes consulting service for foreign governments, has been engaged in the engineering of preparation equipment for the U. S. coal industry for more than 25 years.

Gifford V. Leece has been elected president of Gardner-Denver Co., Quincy, Ill., and **Benjamin C. Essig** has been elected executive vice president. Mr. Leece, who has been vice president and sales manager since 1947, joined the company in 1922. Mr. Essig, who has served for some time on the executive committee, joined Gardner-Denver in 1923. He is a former president of the Denver Chamber of Commerce and of the Manufacturers' Assn. of Colorado.

J. E. M. Wilson, vice president and manager of the mining div., Jeffrey Mfg. Co., Columbus, Ohio, has been elected vice president in charge of sales. **A. R. Anderson** is now general manager of sales for the mining div., **Lincoln Kilbourne** is general manager of sales, conveyor div., and **J. B. McNaughton** is general manager of sales, special products div.

Arthur Scott Shoffstall, former general manager, International Nickel Co., New York, headed the list of five alumni of Pennsylvania State University, State College, Pa., who were selected for Distinguished Alumnus awards for 1954. Mr. Shoffstall was a member of the class of '00. The four other recipients were **Jesse B. Warriner,** '05, first president, Lehigh Navigation Coal Co., Lansford, Pa.; **William B. Wallis,** '11, president, Pittsburgh Lectromelt Furnace Corp., Pittsburgh; **Robert W. Ostermayer,** '17, president, Pennsylvania Industrial Chemical Corp., Clairton, Pa.; and **Paul Weir,** '19, chairman of the board, Paul Weir Co., Chicago.

E. J. Langevad, mine superintendent Macalder-Nyanza Mines Ltd., Kenya, is now mine superintendent, Kilembe Mines Ltd., Kilembe, Uganda, British East Africa.

L. T. Welshans has been named general manager of the newly created cement and coke div. of the Diamond Alkali Co., Cleveland. For the past seven years Mr. Welshans has been technical director at the plant in Painesville, Ohio.

Edward H. Hulse, Westinghouse Electric Corp., has been transferred from Salt Lake City to East Pittsburgh, Pa., as mining, petroleum, and chemical section manager in the Westinghouse industry engineering dept.

William Conrad Browning, consulting engineer, Los Angeles, was awarded the University of Utah's first honorary Doctor of Engineering degree for his leadership "in the development of the West through the winning and preparation of its mineral values . . ." Mr. Browning, a 1907 graduate, is now serving his third term on the California State Mining Board.

James W. Morgan, president of Ayrshire Collieries Corp. of Indianapolis, and **Robert L. Hair,** superintendent of fuel mines of the Colorado Fuel & Iron Corp., Pueblo, Colo., are new members of the board of directors of Bituminous Coal Research Inc., Pittsburgh.

Arno C. Fieldner, chief fuels technologist, U. S. Bureau of Mines, received the honorary degree of Doctor of Science on June 5 from the University of North Dakota, Grand Forks.

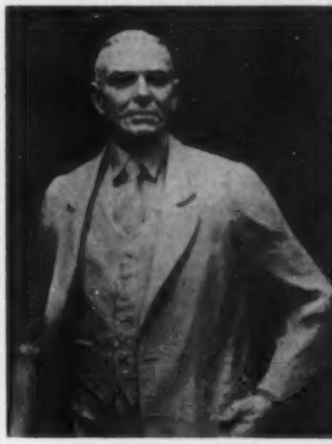
J. G. McDonnell, graduate engineer of the University of Michigan, recently joined the staff of S. P. Kinney Engineers Inc., Carnegie, Pa., in an engineering and sales capacity.

Robert R. Weideman, who was manager for Silver Dollar Mining Co., Wallace, Idaho, has been appointed mine manager for Inspiration Lead Co.'s property north of Wallace. He will also direct the firm's project at Oro property near Troy, Mont.

Harvey L. Tedrow of Denver, who is associated with London Mining & Milling Co. of Colorado, has been named a director of Leadville Lead Corp. This company is now operating uranium properties in Lisbon Valley, San Juan County, Utah.

James H. Wren's photograph appeared on the June cover of *Mining and Industrial News.* Mr. Wren, consulting engineer, Sacramento, Calif., and **E. J. Boback** of El Dorado are reopening the Sugar Loaf-Monarch gold mine in El Dorado County, Calif., an early day producer of high grade gold ore.

E. L. Farrell has been appointed district manager for the Milwaukee territory, and **William C. Young** has been made district manager, Great Lakes territory, heavy machinery div., Nordberg Mfg. Co., Milwaukee. Both men studied at Marquette University, School of Engineering.



DANIEL C. JACKLING

An 8-ft bronze statue of **Daniel C. Jackling,** founder of the Utah Copper Co. and an internationally known mining engineer and industrialist will be placed in the rotunda of the Utah State Capitol this summer. The statue is being created by **Avard Fairbanks,** head of the University of Utah School of Fine Arts, under a commission from the Sons of Utah Pioneers, Jackling Memorial Committee. Directors of Kennecott Copper Corp. appropriated $35,000 for the statue. The photograph above shows a portion of the 4-ft scale model.

Daniel C. Jackling, one of the outstanding figures in the development of the copper industry, has been called the "father of the porphyries" in recognition of his well-known work on the first great low grade copper operation. Fifty years ago Mr. Jackling developed theories of mass mining and processing that are used throughout the world today. His vision made possible the development of one of the world's largest copper mines at a time when experienced mining men said ore of such low grade could not be mined profitably.

In addition to founding Utah Copper Co., Mr. Jackling had an important role in the operation of Nevada Consolidated Copper Co., Ray Consolidated Copper Co., Chino Copper Co., and many other mining and industrial corporations. He has retired as an officer and director of most of these corporations and now lives in the San Francisco area.

Mr. Jackling served several terms as a Director of AIME and was President of the Institute in 1938. He was awarded the William Saunders Medal in 1930 and the John Fritz Medal in 1933. AIME's first Daniel C. Jackling Lecture was inaugurated last February at the Annual Meeting with **Reno H. Sales** as speaker.

HOLLIS G. PEACOCK

Hollis G. Peacock, formerly a geologist with U. S. Smelting Mining & Refining Co., Boston, has been made assistant to **Fred S. Mulock,** president.

H. W. Straley, III, geologist and geophysicist, Princeton, W. Va., has just completed leading a gravity investigation in southern Georgia.

Pope Schoenberger is construction and mining engineer, Brown & Root Inc., New Orleans. He was with Quick Seven Mines, American Zinc & Smelting Co., Joplin, Mo.

Hubert O. De Beck of Johnson City, Tenn., recently fulfilled a long-term commitment as consulting engineer to the U. S. Bureau of Mines, Norris, Tenn., and has accepted an engagement as consulting mining engineer, Baroid Sales Div., National Lead Co.

Curtis L. Wilson, dean of the Missouri School of Mines & Metallurgy, Rolla, Mo., was one of four men outstanding in their fields awarded honorary degrees by Washington University, St. Louis, at its 93rd annual commencement in June. Mr. Wilson, author of *Metallurgy of Copper* and chairman of a five-man committee to investigate the organization and operation of the U. S. Bureau of Mines, was identified as an "outstanding engineer, educator, and head of a distinguished . . . educational institution."

Jorge Quintana S., Lima, Peru, is in the U. S. visiting the Homestead Mining Co., Lead, S. D. He also plans to visit other mining operations in the West.

Frank C. Pickard, who was mine superintendent, Tsumeb Corp. Ltd., Tsumeb, S. W. Africa, is mining consultant, Gregg Car Co. Ltd., Brussels, Belgium.

Lewis J. Hash is employed as a geologist by Zonolite Co., Travelers Rest, S. C.

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AUGUSTUS B. KINZEL

Augustus B. Kinzel, Vice President AIME, has been appointed director of research, Union Carbide & Carbon Corp., New York. Mr. Kinzel has been actively engaged in research work with UC&C since 1926, when he joined Electro Metallurgical Co. as a research metallurgist. He became chief metallurgist of the laboratories in 1931, and a vice president of the company in 1944.

John W. Gardner has been elected a director of Gardner-Denver Co. Mr. Gardner is a 1941 graduate of Missouri School of Mines and served as a lieutenant commander in the Navy during World War I. He joined the company's Los Angeles sales division in 1945 and in 1951 was transferred to its executive offices in Quincy, Ill. At present Mr. Gardner is employed in the engineering development section, relative to new industrial applications for Gardner-Denver's products.

James K. Richardson, assistant to the general manager of Utah copper div., Kennecott Copper Corp., has been elected to the board of governors, Salt Lake City Chamber of Commerce, to serve for three years. Mr. Richardson is a member of the Chamber of Commerce mining committee.

Donald G. Ashe has joined the engineering staff of the Allen-Sherman-Hoff Pump Co. with headquarters in Wynnewood, Pa. He was with Cananea Consolidated Copper Co., Sonora, Mexico. Mr. Ashe was born in Chuquicamata, Chile, and received his degree in metallurgical engineering from Colorado School of Mines.

Roy D. Haworth, Jr., is abrasive engineer, American Wheelabrator & Equipment Corp., Detroit. He was metallurgical manager of products development, Allegheny Ludlum Steel Corp., Ferndale, Mich.

D. J. Ottley has been transferred from La Oroya to Morococha, Peru, where he is general mill foreman, Morochocha concentrator for Cerro de Pasco Corp.

JAMES D. FORRESTER

James D. Forrester, professor and chairman of the dept. of mining engineering at the School of Mines and Metallurgy, University of Missouri, Columbia, has accepted the deanship of the School of Mines at the University of Idaho, Moscow. Mr. Forrester was formerly on the Idaho staff as professor and head of the dept. of geology from 1939 to 1944, and he served as acting dean for four months in 1940. Mr. Forrester, the author of *Principles of Field and Mining Geology, A Laboratory Manual for Physical Geology,* and co-author of *The Pacific Northwest,* has also done extensive writing on mining for encyclopedias and science books. His successor at Missouri School of Mines is **George B. Clark,** professor of mining engineering at the University of Illinois. Mr. Clark received his M.S. in mining engineering from the University of Utah in 1946, his E.M. and Ph.D. degrees from the University of Illinois in 1949 and 1952. A new type of flow measuring manometer was recently perfected by Mr. Clark for measuring air flow in mine ventilation and fan studies, and is being patented by him.

Frank G. Breyer and **Gerhard E. Sonderman,** partners in the New York firm, Singmaster & Breyer, and **Charles Owen Brown,** one of the pioneers in the development of ammonia synthesis, attended the opening of a $7 million nitrate plant near Reykjavik, Iceland. Design and installation-supervision contract for this plant, now producing at the rate of 22,000 tons a year, was given jointly to Singmaster & Breyer and Mr. Brown. In recognition of the part the factory serves in Iceland's economy and industrial development, Mr. Breyer, Mr. Sonderman, and Mr. Brown were awarded the republic's only decoration, the Order of the Falcon.

K. W. B. Iten has resigned as geologist-in-charge, Cerro de Pasco Corp. geological dept., Cerro de Pasco, Peru, and has accepted a position with Benguet Consolidated Mining Co., Baguio City, Mt. Province, P. I.

Russell T. Drennan has been named general sales manager for Kaiser Chemicals Div., Kaiser Aluminum & Chemical Corp., Oakland, Calif., and **John Minshall** has been named eastern regional sales manager for the chemical div., Akron, Ohio. Mr. Drennan joined Kaiser Chemicals in 1946 as chief chemist of the company's Baton Rouge, La., alumina plant. Mr. Minshall joined the company in 1941 in the then operating magnesium foundry, later becoming senior sales engineer in Oakland.

C. Howard George has been elected executive vice president, New Jersey Zinc Co. and **L. S. Holstein** has been elected vice president. Mr. George, a vice president for the past ten years, has been with the company for 39 years. Mr. Holstein, who has been with the company for 42 years, served for many years as general manager of manufacturing and since 1947 as assistant to the president.

Luis A. Nogales, general manager of the ex-Aramayo Mines and Bolivian Tin & Tungsten Corp., has been promoted to general production superintendent, Corporación Minera de Bolivia, La Paz, Bolivia.

John T. Moran is employed as a mining engineer by the National Lead Co., smelting & refining div., Fredericktown, Mo.

E. C. BITZER

E. C. Bitzer has resigned as metallurgical adviser, Div. of Raw Materials, Atomic Energy Commission, Washington, D. C., a position he has held for more than two years. He is returning to his former residence in Golden, Colo., where he will be engaged in his own consulting practice.

Paul H. Brabant, mining engineering, formerly with Belgian Line, New York, and with Pierce Management, Scranton, Pa., has gone to Korea with the UNKRA.

C. D. Ramsden has been named vice president and chief engineer, Pacific Coast Engineering Co., Alameda, Calif.

H. HERBERT HUGHES

H. Herbert Hughes has been elected vice president for Europe of Porter International Co., Washington, D. C. Mr. Hughes, formerly Washington representative for the Studebaker Corp., will take over directorship of the company's European affairs in August with his headquarters in Zurich, Switzerland.

H. Gerald Maiers, who was plant engineer, Titanium Metals Corp. of America, Henderson, Nev., is project engineer, general engineering dept., National Lead Co., New York.

Herbert D. Fine is general manager, Bald Mountain Mining Co., Trojan, S. D.

H. I. Altshuler has been appointed consulting mining engineer by the board of St. John d'el Rey Mining Co. Ltd., Minas Gerais, Brazil. On his return north Mr. Altshuler will visit properties of the New York & Honduras Rosario Mining Co. for which he is also retained as consultant.

D. W. Tittman, metallurgical engineer, St. Joseph Lead Co., Bonne Terre, Mo., is now with Erie Mining Co., Aurora, Minn.

John W. Dent has been elected executive vice president, Georgia Marble Co., Tate, Ga. Mr. Dent has been vice president and head of the calcium products div. since June 1947. This division will now be headed by **T. J. Durrett, Jr.**, who has been a vice president for 10 years and in charge of all engineering. **James R. Cowan** is president of Georgia Marble, which has plants and quarries in Georgia, Alabama, Missouri, Tennessee, Vermont, and California.

George T. Hanson, who was with Anaconda Copper Mining Co., Anaconda, Mont., has transferred his services to Anaconda Aluminum Co., Columbia Falls, Mont. A few months ago Mr. Hanson spent several weeks at an aluminum reduction plant in Savoie Province of the French Alps.

A. E. Roberts, Jr., formerly field editor of *Mining World,* is district manager of the publication with his headquarters in New York.

CHARLES GOTTSCHALK

Charles Gottschalk, U. S. Bureau of Mines, has been assigned to the Philippine Islands for two years. This mission is directly related to performing technical assistance under an arrangement in effect between the Foreign Operations Administration and the Bureau of Mines. His address is FOA-STEM, APO 928 c/o Postmaster, San Francisco.

George T. Harley, for ten years manager of International Minerals & Chemical Corp.'s potash mines at Carlsbad, N. M., has retired from the company and plans to engage in private practice as a geological and mining consultant.

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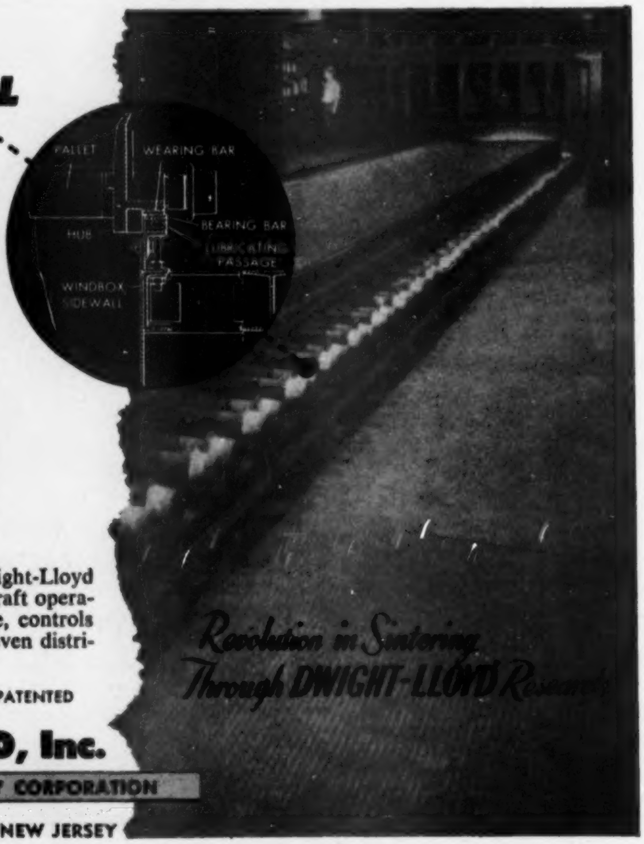

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Obituaries

Walter James Eaton (Member 1917) of San Juan Capistrano, Calif., died June 5, 1954. Mr. Eaton was a consulting mining engineer. He was born in Riverton Neb., in 1888, and after receiving his E.M. from Colorado School of Mines in 1913, gained his early experience as a sample "bucker," assistant assayer and chemist, with Grandby Consolidated Mining, Smelting, & Power Co., Grand Forks, B.C. He also worked as an engineer and assayer for Imperial Reduction Co. and for Plymouth Consolidated Gold Mines, in California. Later he was mine superintendent for San Francisco Mines of Mexico, Parral Consolidated Mining Co., American Smelting & Refining Co. with the Santa Barbara unit at Chihuahua, Mexico, and mine superintendent with Patiño Mines and Enterprises in Bolivia.

William Otis Hotchkiss (Member 1917) of Scarsdale, N.Y., died June 20, 1954. He was president emeritus of Rensselaer Polytechnic Institute and a consulting geologist. Mr. Hotchkiss was born in Eau Claire, Wis., in 1878. While attending the University of Wisconsin he worked as a recorder with the USGS, as a geologist and engineer with Donora Mining Co., Duluth, and as chief of the Leith Exploration party in Ontario. He was graduated from the university with a B.S. in general engineering in 1903, with a C.E. in 1908, and a Ph.D. in 1916. From 1904 to 1907 Mr. Hotchkiss was an instructor in petrography and mineralogy at the University of Wisconsin.

Mr. Hotchkiss was Wisconsin State Geologist from 1909 to 1925 and from 1911 to 1925, he was a member of the Wisconsin Highway Commission, of which he was chairman for two years. He was president of Michigan College of Mining and Technology from 1925 to 1935 and president of RPI from 1935 to 1943. During World War I Mr. Hotchkiss started the War Minerals Commission and during World War II he held the rank of brigadier general with the Army Specialist Corps. He was a fellow of the Geological Society of America, president of the Society of Economic Geologists in 1946, a member of AAAS, and other organizations. He was the author of *Mineral Land Classification of Northern Wisconsin*, *Story of a Billion Years*, and *Minerals of Might*.

Otto Henry Metzger (Member 1951) died Apr. 17, 1954. He was valuation mining engineer, U. S. Bureau of Land Management, Salt Lake City. Mr. Metzger was born in 1894 and received his E.M. from Colorado School of Mines in 1919. After working as a field engineer for Ed. Millard & Sons, Ely, Nev., he went to Cuba as a mining engineer for Matahambre Coppermines. He was later general mine foreman for Sunnyside Mining & Milling Co., Silverton, Colo., mine engineer for Inspiration Coppermines Co., Inspiration, Ariz., and Teck Hughes Gold Mines Ltd., Kirkland Lake, Ont. From 1932 to 1936 Mr. Metzger was mine superintendent, Marian Mining Co., Monte Vista, Colo., and from 1936 to 1943 he was senior mining engineer, U. S. Bureau of Mines. Before joining the U. S. Bureau of Land Management in 1949, Mr. Metzger worked for Union Mines Development Corp., Grand Junction, Colo., and Small Leasing Co., Wallace, Idaho.

Stephen Royce (Member 1909) died June 12, 1954. He was chief geologist, Pickands, Mather & Co., Crystal Falls, Mich. and for more than 30 years specialized in long-range planning and forecasting of mine development. Mr. Royce was an expert in exploring for iron and manganiferous ore. He was born in Cambridge, Mass., in 1889, the son of Josiah Royce, Harvard University philosopher. Mr. Royce received his A.B. and S.B. in mining and metallurgy from Harvard in 1911, having gained practical experience as a millman and ore sampling foreman in 1908 for Nevada Consolidated Copper Co., McGill, Nev., and as a miner and surveyor for Monarch mine, Murray, Idaho, in 1909. He became chief engineer, Low Moor Iron Co., Va., in 1911. After a period of independent practice, scouting, and examination in western states, he worked as chief engineer for Pickands, Mather & Co. on the Gogebic Range from 1912 to 1917, returned to private practice, and then rejoined this company in 1920. The author of numerous technical articles, Mr. Royce was a fellow of the Society of Economic Geologists, AAAS, and a member of the National Society of Professional Engineers.

Adam L. Schneider (Member 1938) died Feb. 23, 1954. He was a consulting mining engineer and a former manager and director of Nova Scotia Gold Mines Ltd. Mr. Schneider was born in Chicago in 1891 and studied at Lane Technical School. Before serving overseas with the AEF during World War I he worked for the Rechsteiner Mfg. Co., Chi-

Necrology

Date Elected	Name	Date of Death
1898	James Colquhoun	June 17, 1954
1917	Walter James Eaton	June 5, 1954
1917	W. O. Hotchkiss	June 20, 1954
1951	Otto Henry Metzger	Apr. 17, 1954
1909	Stephen Royce	June 12, 1954
1949	Charles H. Scheuer	Unknown
1946	K. A. Spohr	May 9, 1954
1937	G. T. Walters	May 26, 1954

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cago, and F. E. Herma & Co., New York. Mr. Schneider was later general manager and director, Bradford Mines Ltd., general manager, Tangier Mining & Power Co., and consulting engineer and manager of the Nova Scotia Gold Mining Syndicate. He was a member of the Nova Scotia Mining Society and the Canadian Institute of Mining and Metallurgy.

Proposed for Membership

MINING BRANCH, AIME

Total AIME membership on June 30, 1954 was 21,033; in addition 1697 Student Associates were enrolled.

ADMISSIONS COMMITTEE

O. B. J. Fraser, Chairman; R. B. Caples, Vice-Chairman; F. A. Ayer, A. C. Brinker, R. H. Dickson, Max Gensamer, Ivan A. Given, Fred W. Hanson, T. D. Jones, Sidney Rolle, J. H. Scaff, John T. Sherman, F. T. Sisco, Frank T. Weems, R. L. Ziegfeld.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

Arizona
Phoenix—Hoag, Leslie F. (M)
Phoenix—O'Gara, Emmett H. (A)
San Manuel—Passavant, Charles R., Jr., (R. C/S-S-M)

Colorado
Denver—Goddard, Paul L. (M)

Illinois
Rosiclare—Blecheisen, Jacob (A)

Minnesota
Eveleth—Hurd, Donald E. (J)
Hibbing—Englund, John O. (J)

Montana
Trident—Burriss, Charles S. (R. C/S—S-M)

New Jersey
Morristown—Hankin, Montagu, Jr. (M)

North Dakota
Fargo—Anders, Franklin L. (R. M)

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— Coming Events —

Sept. 8-10, American Society of Mech. Engrs., fall meeting, Schroeder Hotel, Milwaukee.

Sept. 9, AIME, San Francisco Section, Engineers' Club, San Francisco. AIME President Leo F. Reinartz, speaker.

Sept. 10, AIME Lehigh Valley, annual inspection trip, Ingersoll-Rand Co., Phillipsburg, N. J.

Sept. 12-16, American Institute of Chemical Engineers, national meeting, Hotel Colorado, Glenwood Springs, Colo.

Sept. 13-14, American Coke & Coal Chemicals, annual meeting, The Homestead, Hot Springs, Va.

Sept. 15-29, International Union of Geodesy & Geophysics, 10th general assembly, Rome, Italy.

Sept. 20-24, American Mining Congress, Civic Auditorium, San Francisco.

Sept. 23-24, Central Pennsylvania Coal Producers Assn., annual meeting, Bedford Springs Hotel, Bedford, Pa.

Sept. 24, AIME, Minerals Beneficiation Div., fall meeting, Fairmont Hotel, San Francisco.

Sept. 26-29, American Society of Mechanical Engineers, Petroleum Mechanical Engrg. Conference, Hotel Statler, Los Angeles.

Sept. 30, AIME Utah Section, stag; cocktails, dinner, smoker, 7:00 pm Newhouse Hotel.

Oct. 5-9, AIME Industrial Minerals Div., fall meeting, Whiteface Inn, Lake Placid, N. Y.

Oct. 14-16, New Mexico Mining Assn. and El Paso International Mining Assn., joint convention, Carlsbad, N. M.

Oct. 14-16, Drilling Symposium, University of Minnesota, Minneapolis.

Oct. 17-20, AIME Petroleum Branch, Plaza Hotel, San Antonio.

Oct. 18-22, American Society of Civil Engineers, annual meeting, Hotel Statler, New York.

Oct. 18-22, National Safety Congress and Exposition, Chicago, Ill.

Oct. 26, Assn. of Consulting Chemists and Chemical Engineers Inc., annual symposium and banquet, Hotel Belmont Plaza, New York.

Oct. 27-29, Clay Mineral Technology, Third National Clay Minerals Conference, Rice Institute, Houston.

Oct. 28-29, Engineers' Council for Professional Development, Hotel Alms, Cincinnati.

Oct. 28-29, AIME, ASME Fuels Conference, William Penn Hotel, Pittsburgh.

Oct. 29, AIME, NOHC and Pittsburgh Local Section, off-the-record meeting, William Penn Hotel, Pittsburgh.

Oct. 29-30, AIME, Industrial Minerals Div., Rocky Mountain Region Industrial Minerals Conference, Salt Lake City. Registration Oct. 28.

Oct. 30, AIME, Utah Section, annual fall cocktail party, dinner dance, 7:00 pm, Newhouse Hotel, Salt Lake City.

Nov. 1-3, AIME, Institute of Metals Div., fall meeting, Hotel Morrison, Chicago.

Nov. 1-3, Geological Society of America and Associated Societies, Statler and Biltmore hotels, Los Angeles.

Nov. 8-11, American Petroleum Institute, 34th annual meeting, Conrad Hilton Hotel and Palmer House, Chicago.

Nov. 12, Illinois Mining Institute, Hotel Abraham Lincoln, Springfield, Ill.

Nov. 18, AIME, Utah Local Section, joint meeting with Intermountain Assn. of Petroleum Geologists, 8:00 pm, Newhouse Hotel, Salt Lake City.

Nov. 18, American Mining Congress, Coal Div., Wm. Penn Hotel, Pittsburgh.

Nov. 28-Dec. 3, American Society of Mechanical Engineers, annual meeting, Hotel Statler, New York.

Dec. 1-4, AIME Electric Furnace Conference, William Penn Hotel, Pittsburgh.

Dec. 12-15, American Institute of Chemical Engineers, annual meeting, Statler Hotel, New York.

Dec. 26-31, American Assn. for the Advancement of Science, national meeting, University of California, Berkeley, Calif.

Feb. 14-17, 1955, AIME, Annual Meeting, Conrad Hilton Hotel, Chicago.

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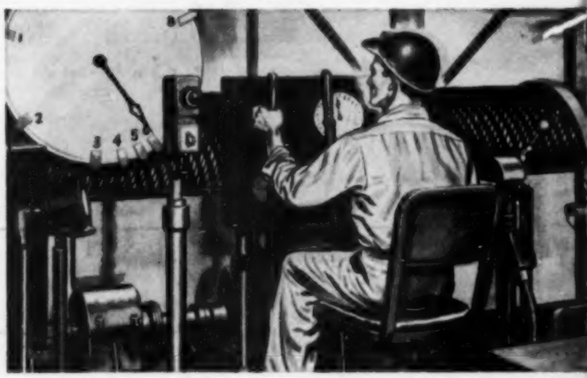

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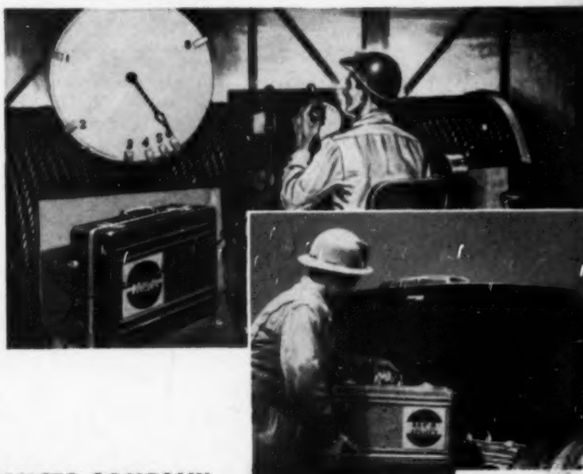

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